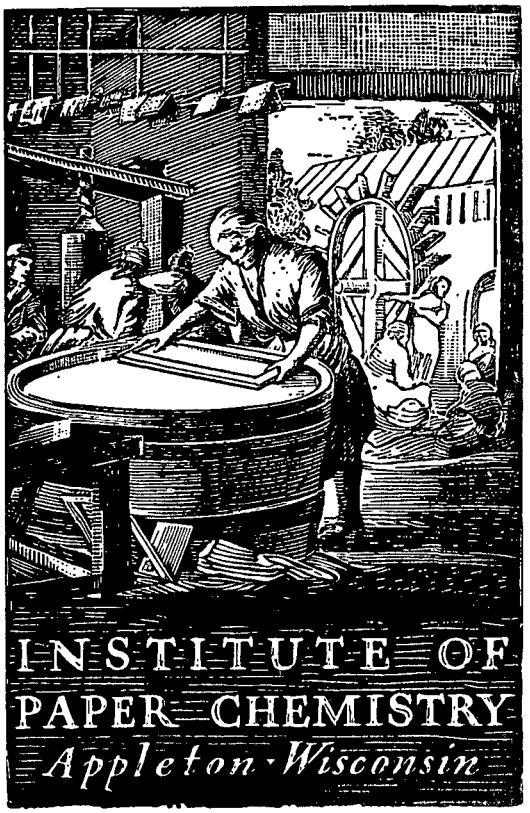

STUDY OF THE USE OF WASTE PAPER IN KRAFT LINERBOARD

PHASE II. EFFECT OF ADDING SECONDARY STOCK ON THE PROPERTIES OF KRAFT LINERBOARD

Project 2695-13

Report Two

A Progress Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

October 31, 1972

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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SUMMARY

A study has been carried out to determine the effect of adding two types of paper stock to an unbleached kraft furnish on strength characteristics, and in particular the bursting strength characteristics of the resulting handsheets. The paper stocks were (1) double-lined kraft corrugated cuttings and (2) corrugated containers. The unbleached kraft pulp was refined to two levels, i.e., 590 and 355-ml. Canadian Standard freeness, and the paper stock to three levels, i.e., 585 or 575, 355 and 205-ml. Canadian Standard freeness. The lowest freeness level of each paper stock represents the level of maximum bursting strength of that paper stock. Test handsheets were prepared from furnishes containing the following proportions of kraft pulp to paper stock: 100:0, 90:10, 80:20, and 60:40.

The results obtained may be summarized as follows:

1. The bursting strength of the handsheets made from the 590-ml. freeness kraft pulp and 585, 355, and 205-ml. freeness double-lined kraft corrugated cuttings decreased with increase in percentage of paper stock in the furnish. Except in a few cases — e.g., tearing strength and Z-direction tensile — all the other properties evaluated tended to either decrease or remain essentially constant. Tearing strength appeared to go through a maximum with increase in percentage of paper stock at the 585 and 355-ml. freeness levels; at the 205-ml. freeness level

tearing strength decreased. The same general trend was observed for the handsheets made from 355-ml. freeness kraft pulp and 355 and 205-ml. freeness double-lined kraft corrugated cuttings. The greater the degree of refining of the paper stock, the lower the loss in bursting strength with increase in percentage of paper stock for the handsheets made with furnishes containing kraft pulp at 590-ml. freeness.

In the case of the blends containing kraft pulp at 355-ml. freeness, bursting strength appeared to be essentially independent of the degree of refining of the paper stock. In general, density, tensile strength, tensile energy absorption, and porosity value tended to increase with increasing degree of refining of the paper stock whereas tearing strength tended to decrease.

2. The bursting strength of the handsheets made from the 590-ml. freeness kraft pulp and 575, 355, and 205-ml. freeness corrugated containers decreased with increase in the percentage of paper stock in the furnish. Except in the case of tearing strength, all the other properties either decreased or remained essentially constant with increase in the percentage of paper stock in the furnish; tearing strength appeared to go through a maximum with increase in the percentage of paper stock. The greater the degree of refining of the paper stock, the lower the loss in bursting strength with an increase in the percentage of paper stock for the handsheets made with furnishes containing kraft pulp at 590-ml. freeness. In the case of the furnish involving blends of 355-ml. freeness kraft pulp, bursting strength also decreased with an increase in the

percentage of paper stock in the furnish. Density, tensile strength, and Z-direction tensile decreased whereas tensile energy absorption and porosity remained essentially constant with an increase in the percentage of paper stock. Tearing strength appeared to pass through a maximum with an increase in the percentage of paper stock at the 355-ml. paper stock freeness level but remained essentially constant at the 205-ml. paper stock freeness level.

As was noted for the double-lined kraft corrugated cuttings, increasing the refining of the paper stock blended with the 590-ml. freeness kraft pulp resulted in a decrease in the loss in bursting strength. All other test properties generally increased with an increase in the refining of the paper stock except tearing strength. Tearing strength decreased as would be expected. Increasing the refining of the paper stock blended with the 355-ml. freeness kraft pulp generally resulted in a decrease in strength loss; however, tearing strength, stretch, and Z-direction tensile were not very sensitive to freeness change.

3. Statistical analysis by means of linear regression analysis indicates that the effect of increasing the percentage of paper stock on bursting strength is about the same for the double-lined kraft corrugated cuttings as the old corrugated. The correlation coefficients for the relationship between bursting strength and the percentage of paper stock in the furnish were relatively high for most furnishes and were all negative indicating that bursting strength decreases as the percentage of paper stock in the furnish decreases.

The correlation coefficients for the relationship between tensile strength and the percentage of paper stock used in the furnish were considerably lower in magnitude for the furnishes using a blend of paper stock and kraft pulp refined to 590-ml. freeness than the corresponding coefficients for the bursting strength relationship. The coefficients for the relationship based on blends of paper stock and kraft pulp refined to 355 were high in magnitude comparable to those for bursting strength. In general, the relationship showed that tensile strength decreased with increase in the percentage of paper stock in the furnish.

The correlation coefficients for the relationship between edgewise compression and the percentage of paper stock in the furnish were in general relatively low, indicating that edgewise compression strength was not markedly influenced by the percentage of paper stock in the furnish. In most cases there was no significant difference due to type of paper stock. The correlation coefficients for the relationship between tearing strength and the percentage of paper stock in the furnish ranged from fairly low to low except in one case. This exception was the furnish consisting of kraft pulp refined to 590 ml. and paper stock refined to 205-ml. freeness. The relationship for both paper stocks indicated that tearing strength decreased with increase in the percentage of paper stock.

INTRODUCTION

Project 2695-13 was initiated on behalf of the Fourdrinier Kraft Board Institute, Inc. as a three-phase study related to waste paper utilization technology. The three phases are:

Phase I. Study of the Effect of Type of Fiber on the Rate of Moisture Change, Equilibrium Moisture Content, and Dimensional Stability.

Phase II. Effect of Adding Varying Amounts of Secondary Stock on the Strength Properties of Kraft Linerboard.

Phase III. Effect on Strength Properties of Blending a Repeatedly Repulped Paper Stock with Virgin Kraft Paper.

The work outlined in Phase I has been completed and the results distributed in a report entitled:

Study of Use of Waste Paper in Kraft Linerboard

Phase I. Effect of Type of Fiber on Rate of Moisture Change, Equilibrium Moisture Content, and Dimensional Stability

Project 2695-13, October 10, 1972

Phase II, which is the subject of this report, is concerned with a study of the effect of adding varying amounts of two common types of waste paper which fall in the general class of corrugated waste, namely, Corrugated Containers and Double-Lined Kraft Corrugated Cuttings. These are Grades 10 and 12, respectively, as defined by PS-71, and are the grades of waste customarily used in the manufacture of linerboard.

The interest in this study stems from the fact that it is well-known that the strength of paper made with virgin fibers is normally considerably stronger than when made with the same fiber after one or more repulpings unless considerable energy is expended in refining the secondary stock. In addition, the relatively recent General Services Administration policy wherein certain grades of board supplied the Federal Government must contain a relatively high percentage of recycled fiber of which a given percentage must be postconsumer waste, highlights the need for information as to the effect of adding varying amounts of waste paper on linerboard strength properties. The General Services Administration requirement does not contain any compensating changes in the quality of the board. As mentioned, the major grades of waste paper which normally are used in the production of linerboard fall in the category of corrugated paper stock. Approximately 13-million tons of corrugated board were produced in 1970 and slightly less than 4.5-million tons were recycled.

The corrugated container paper stock used in this phase was part of the same lot used in Phase I. This consisted of a mixture of equal parts of typical packs of corrugated container paper stock obtained from four different regions in this country — i.e., West Coast, North Central, Eastern, and Southern areas. Typical samples of double-lined kraft corrugated cuttings were obtained from these same regions and mixed by repulping equal parts in a laboratory hydrapulper at 2.0% consistency, dewatered and crumbled, and then stored in an airtight container.

The kraft pulp used in this phase was a commercial-grade unbleached kraft pulp. The experimental program followed in determining the effects of adding varying amounts of two grades of secondary paper stock to kraft linerboard is set forth in the following section.

EXPERIMENTAL PROCEDURES

DOUBLE-LINED KRAFT CORRUGATED CUTTINGS

The mixture of double-lined kraft corrugated cuttings was refined in a laboratory beater to three levels of Canadian Standard freeness: (1) 585 ml., (2) 355 ml. and, (3) to the freeness level corresponding to the development of maximum bursting strength of the cuttings.

CORRUGATED CONTAINER STOCK

The mixture of corrugated container paper stock was refined as described above to the same general freeness levels.

UNBLEACHED KRAFT PULP

The unbleached kraft pulp was refined in a laboratory beater to two levels of freeness, namely 590 and 355 ml. The refined pulp at each freeness level was dewatered and crumbled, and then stored in moistureproof containers.

PREPARATION OF HANDSHEETS

Standard British handsheets (1.2 g.) were prepared and air dried using the following stock combinations and proportions:

Double-Lined Kraft Corrugated Cuttings

Kraft Pulp Refined to 590 ml.

a. 100% virgin kraft

b. 90% virgin kraft and 10% kraft cuttings at 585 ml.

c. 90% virgin kraft and 10% kraft cuttings at 355 ml.

d. 90% virgin kraft and 10% kraft cuttings at 205 ml.

[This is the freeness corresponding to maximum bursting strength of the double-lined kraft corrugated cutting.]

e. 80% virgin kraft pulp and 20% kraft cuttings at 585 ml.

f. 80% virgin kraft pulp and 20% kraft cuttings at 355 ml.

g. 80% virgin kraft pulp and 20% kraft cuttings at 205 ml.

h. 60% virgin kraft pulp and 40% kraft cuttings at 585 ml.

i. 60% virgin kraft pulp and 40% kraft cuttings at 355 ml.

j. 60% virgin kraft pulp and 40% kraft cuttings at 205 ml.

Kraft Pulp Refined to 355 ml.

a. 100% virgin kraft

b. 90% virgin kraft and 10% kraft cuttings at 355 ml.

c. 90% virgin kraft and 10% kraft cuttings at 205 ml.

d. 80% virgin kraft and 20% kraft cuttings at 355 ml.

e. 80% virgin kraft and 20% kraft cuttings at 205 ml.

f. 60% virgin kraft and 40% kraft cuttings at 355 ml.

g. 60% virgin kraft and 40% kraft cuttings at 205 ml.

Corrugated Container Stock

The corrugated container secondary stock was used in the same proportions and procedure as described above for the double-lined kraft corrugated cuttings. In the case of the corrugated container secondary stock, the freeness corresponding to maximum bursting strength development was 205 ml.

EVALUATION

Each stock or pulp was evaluated for freeness, fiber classification, and drainage resistance. The latter was measured in terms of the time for the

"free" water to disappear in the British sheet mold when making a handsheet of the furnish in question. In addition, the freeness was determined on each of the mixed furnish used for test handsheets.

The freeness, drainage times, and fiber classification results for the parent stocks are tabulated in Table I.

The experimental handsheets were conditioned at 50 ± 2% relative humidity at 73 ± 3.5°F. and then evaluated for basis weight, caliper, apparent density, bursting strength, tensile stretch, tensile energy absorption, porosity, edgewise compression (modified ring test), Z-direction tensile, and Elmendorf tearing strength.

DISCUSSION OF RESULTS

As mentioned previously, the purpose of Phase II was to investigate the effect of adding varying amounts of secondary paper stock on the properties of kraft linerboard. Of particular or primary concern was the effect on bursting strength inasmuch as this is the only strength property specified in Rule 41. Although Rule 41 strengthwise is concerned with the bursting strength of corrugated and solid fiber combined board, it is well known that the bursting strength of corrugated combined board is primarily dependent upon the bursting strength of the linerboards or facings.

Two paper stocks were used — i.e., double-lined kraft corrugated cuttings and corrugated containers. Each of these paper stocks were refined to different levels of freeness and combined with softwood unbleached kraft pulp, refined to two levels of freeness, in varying proportions and then made into test handsheets. The resulting handsheets were evaluated for a series of properties.

TABLE I

PULP AND PAPER STOCK CHARACTERISTICS

Type Fiber	Canadian Standard Freeness, ml.	Drainage Time, sec.	Fiber Classification, % On 12	Through 12 on 25	Through 35 on 65	Through 65 on 150	Through 150
Virgin kraft	590	4.95	48.5	28.4	12.8	2.7	7.6
Virgin kraft	355	6.82	48.8	26.5	12.3	3.3	9.1
Double-lined kraft corrugated	585	5.02	31.4	33.4	18.8	5.2	11.2
Double-lined kraft corrugated	355	6.19	23.0	29.6	21.4	8.6	17.4
Double-lined kraft corrugated	205	10.36	14.6	25.3	15.7	4.8	39.6
Corrugated container	575	5.29	29.4	32.1	17.9	4.0	16.6
Corrugated container	355	7.12	20.9	28.0	18.2	6.6	26.3
Corrugated container	205	12.58	12.8	22.4	15.9	5.5	43.4

In considering these results it should be borne in mind that the substitution of corrugated waste involves more than substituting reclaimed kraft fibers for virgin kraft fibers. The bulk of corrugated board is comprised of two linerboards and one corrugated medium. There is very little kraft corrugating medium manufactured today and the majority of mediums are either semichemical hardwoods or bogus. The production of corrugating medium is in the ratio of about 4:1 semichemical:bogus. Bogus is the term used to denote corrugating medium made entirely or predominantly from reclaimed paper stock. The percentage of kraft linerboard in double-lined kraft corrugated board will vary with the series combined board, being in the order of 58% for 125 series, 68% for 200 series, and 82% for 350 series. Nearly fifty percent of the kraft linerboard produced is of the grade weight for the 200 series; thus, a reasonable average percentage of kraft linerboard in double-lined kraft corrugated cuttings would be of the order of 68%. The balance is mainly hardwood unbleached semichemical or reclaimed fibers which would not be expected to contribute to bursting strength in the same proportions as the kraft fibers in the linerboard.

EFFECT OF DOUBLE-LINED KRAFT CORRUGATED CUTTINGS

The results obtained on the handsheets made with 0 to 40% double-lined kraft corrugated cuttings are tabulated in Table II and graphically shown in Fig. 1-5. It may be observed in Table II and Fig. 1 that, with the exception of tearing strength factor, all test properties of the handsheets made with a furnish of virgin kraft (590-ml. freeness) and double-lined kraft corrugated cuttings refined to 585-ml. freeness tended to decrease with increase in the percentage of paper stock in the furnish. However, some of the changes such as porosity are not considered significant. The decrease in apparent density implies poorer

TABLE II

PHYSICAL PROPERTIES OF HANDSHEETS MADE WITH VARYING AMOUNTS OF KRAFT PULP AND DOUBLE-LINED CORRUGATED CUTTINGS

	Stock Characteristics						Physical Properties of Handsheets									
	Furnish				Furnish	Drainage					Bursting Strength			Edgewise Compression		
Sample No.	Kraft Percent	Pulp Freeness	Paper Percent	Stock Freeness	Freeness ml. C.S.	Time, sec.	Basis Weight, 25 x 40-500, lb.	Caliper, pt.	Apparent Density	Diff. %	p.s.i.	Factor	Diff. %	lb./in.	Factor	Diff. %
1	0	-	100	585	585	5.02	47.4	5.4	8.8	-23.5	21.2	.45	-49.4	4.20	0.089	-22.6
2	100	590	0	-	590	4.95	47.2	4.1	11.5	-	41.9	.89	-	5.45	0.115	-
3	90	590	10	585	580	4.87	46.3	4.5	10.3	-10.4	38.4	.83	- 6.7	5.00	0.108	- 6.1
4	80	590	20	585	580	4.94	48.1	4.7	10.2	-11.3	39.1	.81	- 9.0	5.40	0.112	- 2.6
5	60	590	40	585	590	4.85	47.5	5.1	9.3	-19.1	33.0	.70	-21.3	4.95	0.104	- 9.6
6	0	-	100	355	355	6.19	46.0	5.1	9.0	-21.7	28.2	.61	-31.5	4.55	0.099	-13.9
7	90	590	10	355	585	4.79	46.1	4.4	10.5	- 8.7	39.0	.85	- 4.5	5.40	0.117	+ 1.7
8	80	590	20	355	580	4.90	46.9	4.3	10.9	- 5.2	38.4	.82	- 7.9	5.05	0.108	- 6.1
9	60	590	40	355	550	5.18	49.1	5.0	9.8	-14.8	39.0	.79	-11.2	5.70	0.116	- 0.9
10	0	-	100	205	205	10.36	45.9	4.7	9.8	-14.8	35.0	.76	-19.1	5.25	0.114	- 0.9
11	90	590	10	205	580	4.86	49.2	4.7	10.5	- 8.7	42.8	.87	- 2.2	5.95	0.121	+ 5.2
12	80	590	20	205	560	4.94	46.6	4.3	10.8	- 6.1	41.5	.89	0.0	5.25	0.113	- 1.7
13	60	590	40	205	505	5.25	46.3	4.5	10.3	-10.4	39.5	.85	- 4.4	5.00	0.108	- 6.1
14	100	355	0	-	355	6.82	46.1	4.0	11.5	-	53.0	1.15	-	5.10	0.111	-
15	90	355	10	355	360	5.69	46.2	4.2	11.0	- 4.3	45.4	0.98	-14.8	5.50	0.119	+ 7.2
16	80	355	20	355	360	5.74	45.5	4.2	10.8	- 6.1	43.0	0.95	-17.4	4.90	0.108	- 2.7
17	60	355	40	355	360	5.85	47.0	4.5	10.4	- 9.6	40.8	0.87	-24.3	5.15	0.110	- 0.9
18	90	355	10	205	325	5.88	46.2	4.2	11.0	- 4.3	44.6	0.97	-15.7	5.15	0.111	0.0
19	80	355	20	205	310	5.91	45.4	4.2	10.8	- 6.1	45.2	1.00	-13.0	5.40	0.119	+ 7.2
20	60	355	40	205	300	5.80	45.2	4.4	10.3	-10.4	40.2	0.90	-21.7	5.15	0.114	+ 2.7

TABLE II (Continued)

PHYSICAL PROPERTIES OF HANDSHEETS MADE WITH VARYING AMOUNTS OF KRAFT PULP AND DOUBLE-LINED CORRUGATED CUTTINGS

Sample No.	Physical Properties of Handsheets												
	Elmendorf Tearing Resistance			Z-Direction Tensile		Porosity		Tensile Strength			Stretch		Tensile Energy Absorption	
	g./Sheet	Factor	Diff.%	lb./in.^{2}	Diff.%	Sec./100 ml.	Diff.%	lb./in.	Factor	Diff.%	Percent	Diff.%	in.-lb./in.^{2}	Diff.%
1	88	1.86	-12.3	59.6	-34.9	4	-42.9	13.9	0.294	-40.2	1.9	-26.9	0.190	-55.4
2	100	2.12	-	91.6	-	7	-	23.2	0.492	-	2.6	-	0.426	-
3	107	2.31	+ 9.0	89.8	- 2.0	4	-42.9	21.8	0.470	- 4.5	2.4	- 7.7	0.374	-12.2
4	100	2.08	- 1.9	87.2	- 4.8	6	-14.3	23.7	0.492	0.0	2.5	- 3.8	0.414	- 2.8
5	102	2.15	+ 1.4	74.8	-10.5	4	-42.9	20.0	0.421	-14.4	2.2	-15.4	0.310	-27.2
6	75	1.63	-23.1	98.4	+ 7.4	21	+200.0	19.1	0.415	-15.7	2.5	- 3.8	0.334	-21.6
7	105	2.28	+ 7.5	94.0	+ 2.6	5	-28.6	23.1	0.501	+ 1.8	2.5	- 3.8	0.406	- 4.7
8	97	2.07	- 2.4	94.8	+ 3.5	8	+14.3	23.6	0.504	+ 2.4	2.4	- 7.7	0.404	- 5.2
9	97	1.98	- 6.6	88.0	- 3.9	9	+28.6	24.6	0.501	+ 1.8	2.6	0.0	0.436	+ 2.3
10	68	1.48	-30.2	111.2	+21.4	86	+1128.5	21.0	0.458	- 6.9	2.5	- 3.8	0.367	-13.8
11	107	2.18	- 2.8	84.4	- 7.9	5	-28.6	24.5	0.499	- 1.4	2.5	- 3.8	0.425	- 0.2
12	92	1.97	- 7.1	95.4	+ 4.1	8	+14.3	24.0	0.516	+ 4.9	2.6	0.0	0.438	+ 2.8
13	84	1.81	-14.6	110.8	+21.0	16	+129.6	23.3	0.503	+ 2.2	2.5	- 3.8	0.409	- 4.0
14	84	1.82	-	128.6	-	46	-	26.5	0.575	-	3.0	-	0.559	-
15	91	1.97	+ 8.2	116.2	- 9.6	30	-34.8	25.1	0.542	- 5.7	2.8	- 6.7	0.478	-14.5
16	88	1.93	+ 6.0	112.4	-12.6	31	-32.6	24.3	0.534	- 7.1	2.6	-13.3	0.428	-23.4
17	87	1.58	-13.2	112.2	-12.8	32	-30.4	24.3	0.517	-10.1	2.8	- 6.7	0.468	-16.3
18	86	1.86	+ 2.2	117.8	- 8.4	40	-13.0	26.1	0.564	- 1.9	2.7	-10.0	0.494	-11.6
19	84	1.85	+ 1.6	119.2	- 7.3	40	-13.0	25.1	0.553	- 3.8	2.9	- 3.3	0.493	-11.8
20	84	1.86	+ 2.2	112.8	-12.3	28	-26.1	23.0	0.509	-11.3	2.7	-10.0	0.441	-21.1

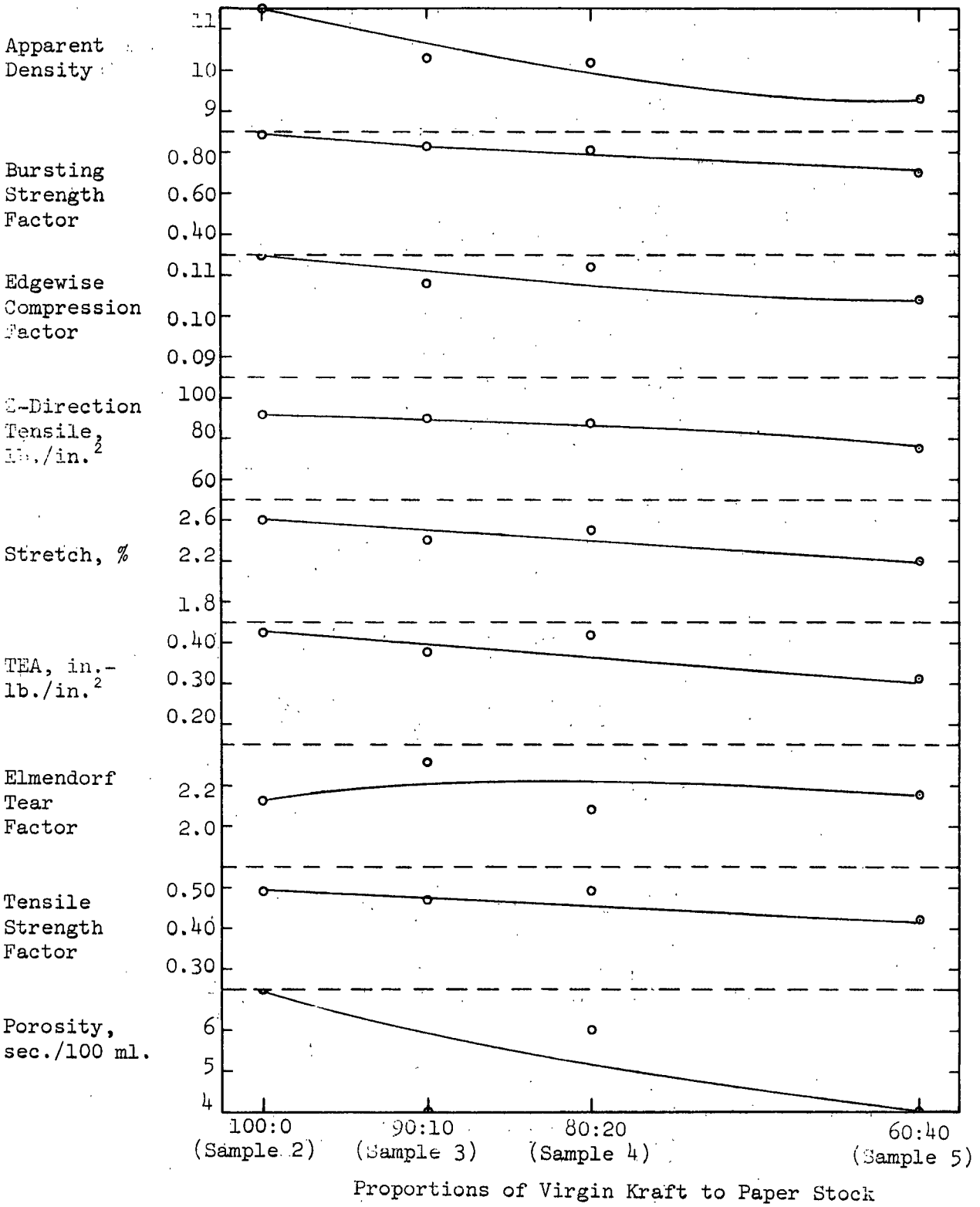

Figure 1. Effect of Varying Proportions of Virgin Kraft (585-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings (585-ml. Freeness) on Sheet Strength

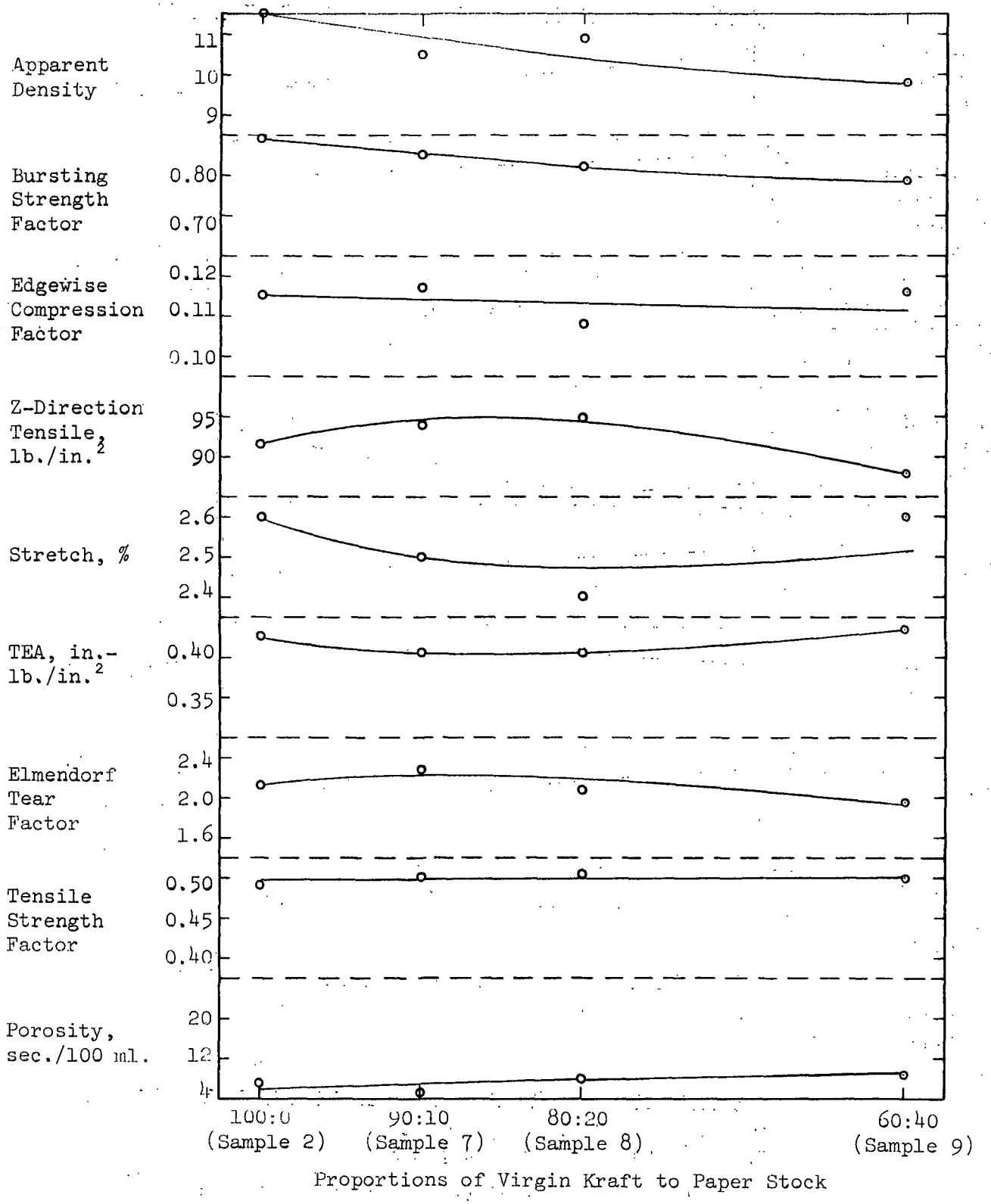

Figure 2. Effect of Varying Proportions of Virgin Kraft (585-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings (355-ml. Freeness) on Sheet Strength

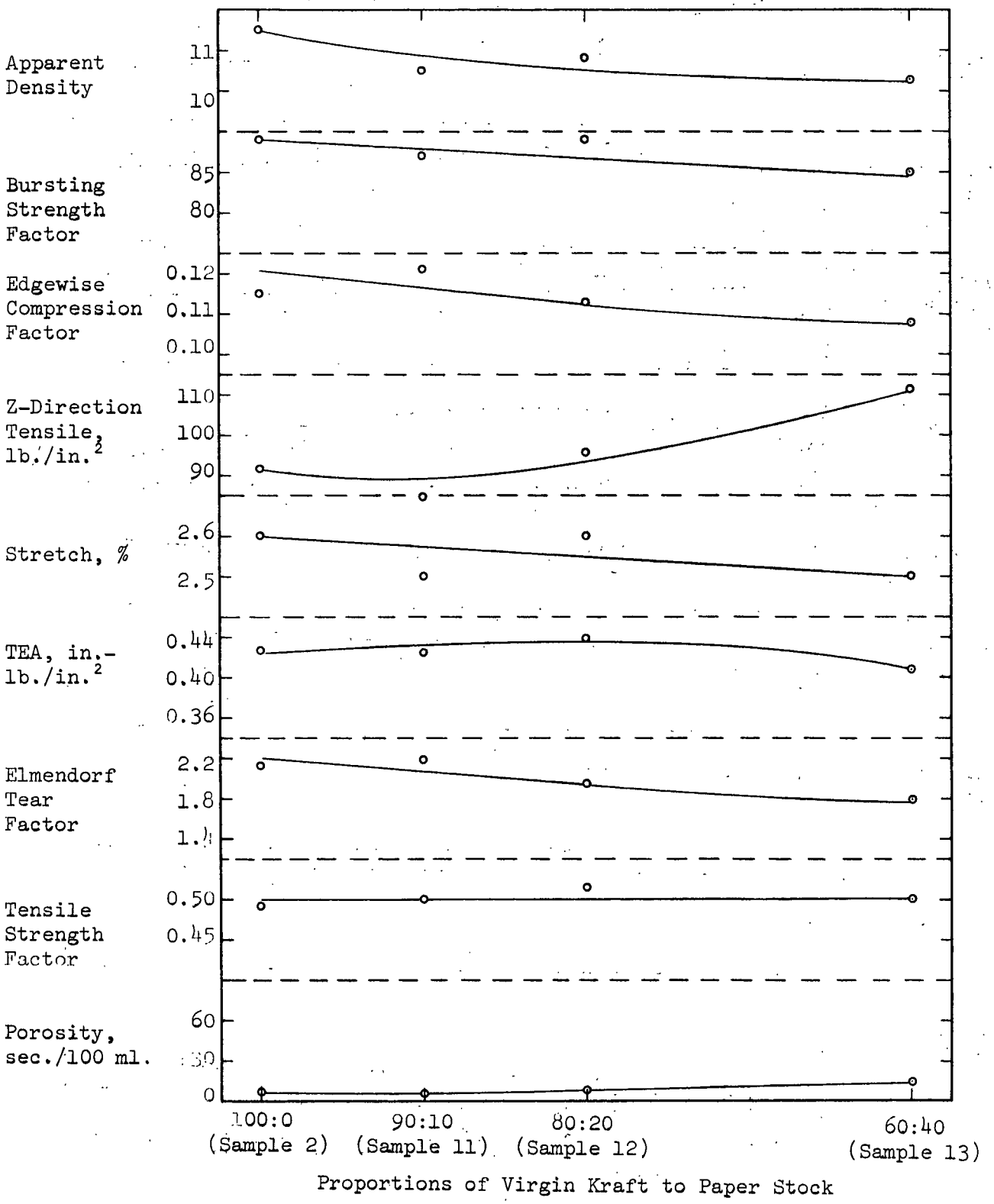

Figure 3. Effect of Varying Proportions of Virgin Kraft (585-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings (205-ml. Freeness) on Sheet Strength

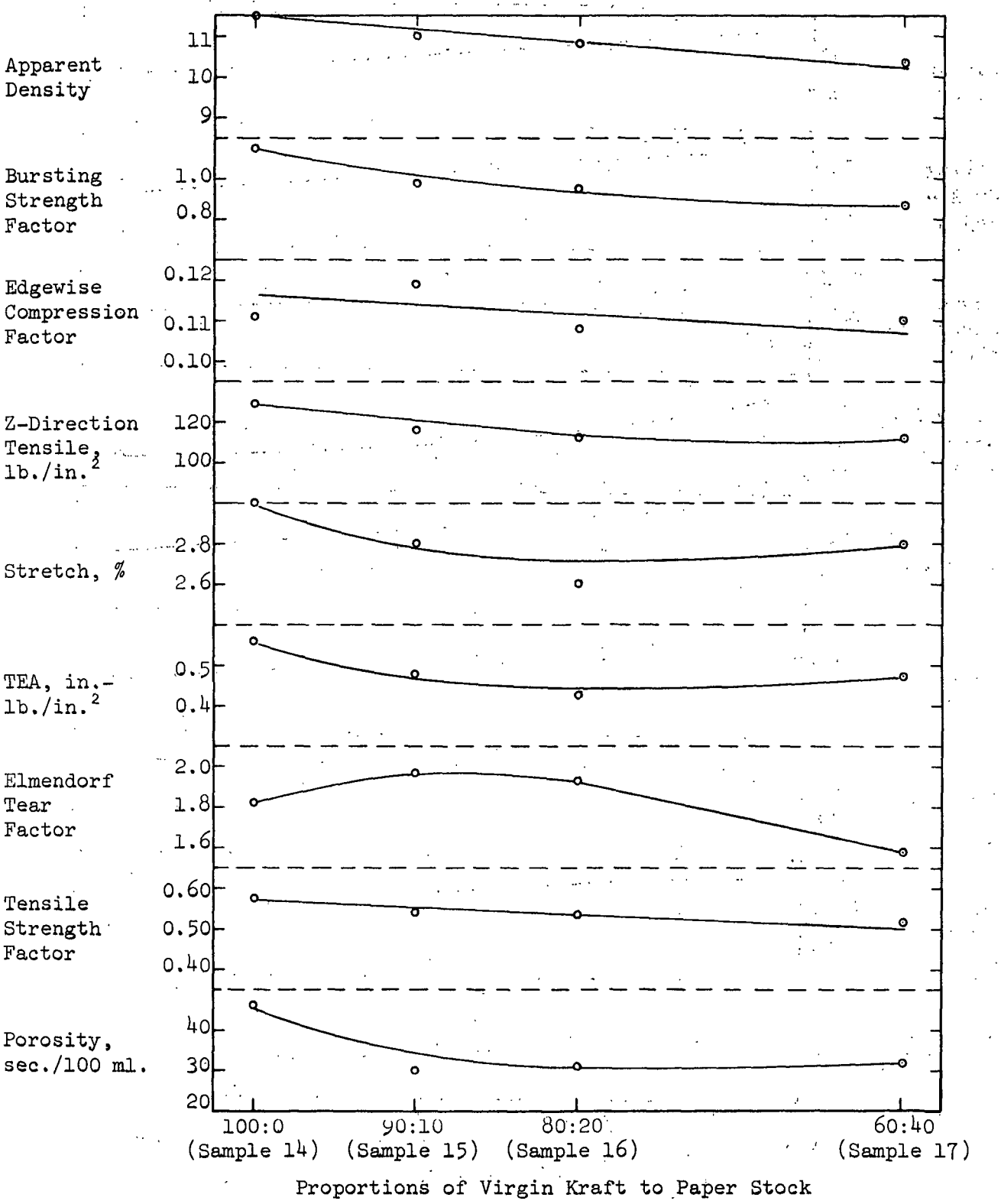

Figure 4. Effect of Varying Proportions of Virgin Kraft (355-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings (355-ml. Freeness) on Sheet Strength

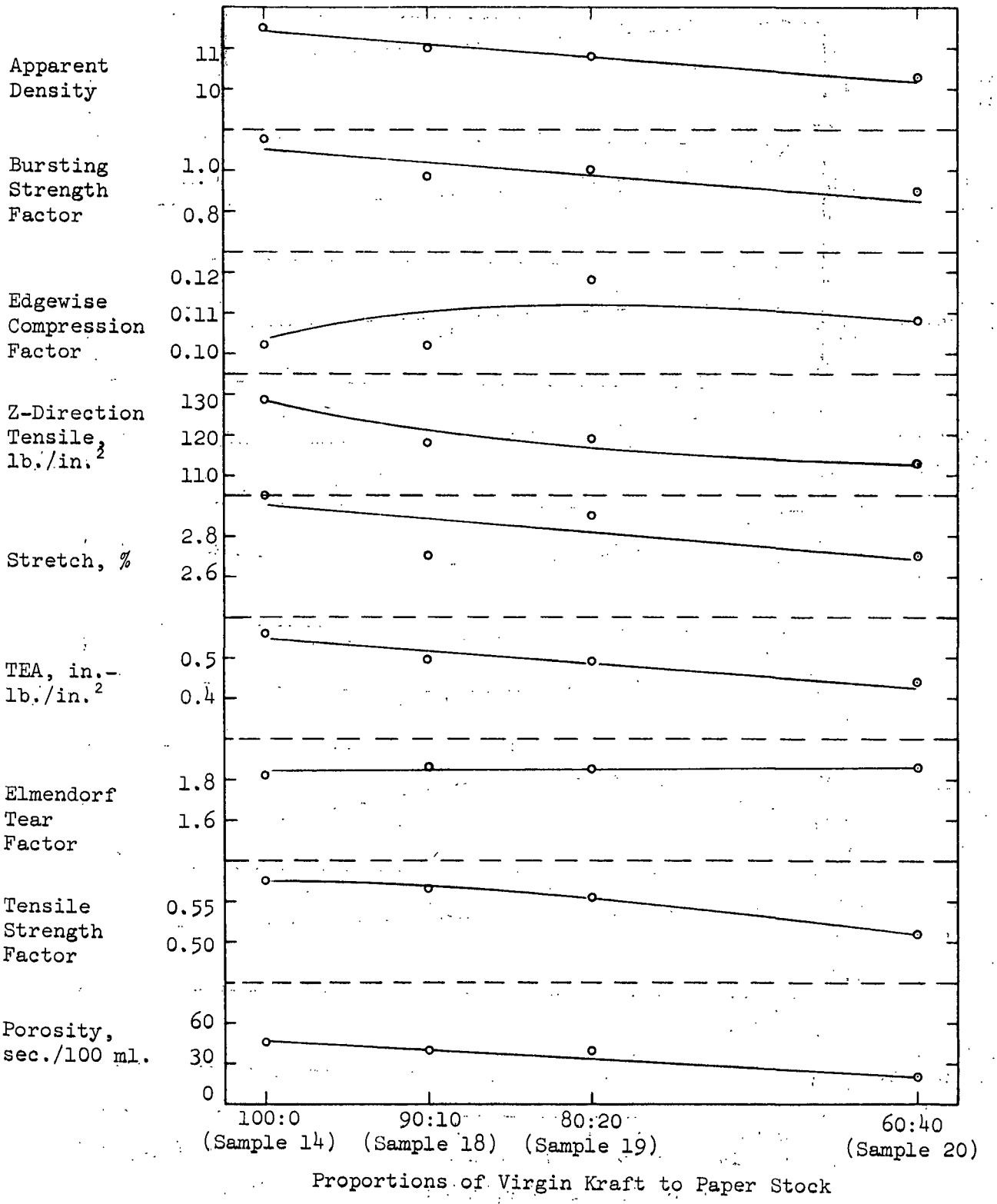

Figure 5. Effect of Varying Proportions of Virgin Stock (335-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings (205-ml. Freeness) on Sheet Strength

fiber-fiber bonding which is supported in part by the Z-direction tensile results. When the corresponding results on handsheets made from the same furnishes, except that the paper stock was refined to 355-ml. freeness, are considered, it may be, in general, apparent that density and bursting strength decreased with increase in the amount of paper stock. Tensile strength, tensile energy absorption, stretch, edgewise compression, and porosity remained essentially constant whereas tearing strength and Z-direction tensile appeared to go through a slight maximum. The handsheets made with the same furnish except that the paper stock was refined to a freeness of 205 ml. (see Fig. 3) exhibited decreasing apparent density, bursting strength, edgewise compression, and tearing strength, but essentially constant tensile energy absorption, tensile strength, stretch, and porosity with increase in the percentage of paper stock in the furnish. In contrast, Z-direction tensile tended to increase with increase in the percentage of paper stock. This is in contradiction to apparent density which decreased. It may be recalled that 205-ml. freeness corresponded to the development of the maximum bursting strength for double-lined kraft corrugated cuttings.

Figures 4 and 5 illustrate the effect of increasing amounts of paper stock on sheet properties when the virgin kraft is refined to 355-ml. freeness and combined with the paper stock refined to 355 and 205 ml., respectively. In the case of both furnishes, all properties tended to decrease except tearing strength and edgewise compression with increase in the amount of paper stock in the furnish.

The above results show that regardless of the degree of refinement of the paper stock, bursting strength decreased with increase in the percentage of paper stock and in the furnish. However, the magnitude of the bursting strength decay decreased with increase in the degree of refining of the paper stock as

may be seen in Fig. 6, 7, and 8 for 90:10, 80:20, and 60:40 furnishes of virgin kraft (590-ml. freeness) and double-lined kraft corrugated cuttings refined to 585, 335, or 205 ml. In all three cases it may be observed that bursting strength increased as the degree of refining increased. This increase, however, was not without its penalty in that the freeness of the mixed furnish decreased with the increased refining of the paper stock and hence poorer drainage would be expected on the paper machine.

In so far as the other properties are concerned, it may be seen that, in general, apparent density, tensile strength, tensile energy absorption, and porosity tended to increase and tearing strength to decrease with increase in the degree of refining of the paper stock in the furnishes. No clear trend was evident for edgewise compression or stretch.

The corresponding effect on handsheets made from furnishes consisting of virgin kraft refined to 335-ml. freeness and the paper stock to 355 or 205 ml. may be seen in Fig. 9, 10, and 11. It may be noted that when the paper stock was mixed with virgin kraft pulp refined to 355-ml. freeness, the decrease in paper stock freeness from 335 to 205 ml. had essentially no effect on bursting strength. When the other test properties were examined, it could be seen that, in general, most of the test properties did not change markedly.

EFFECT OF CORRUGATED CONTAINER PAPER STOCK

The results obtained on the handsheets made with a furnish of 0 to 40% corrugated container stock are given in Table III and illustrated in Fig. 12-16. It may be seen in Fig. 12-14 that, in general, apparent density, bursting strength, edgewise compression, tensile stretch, and tensile energy absorption decreased with increase in the percentage of paper stock in the furnish. Porosity

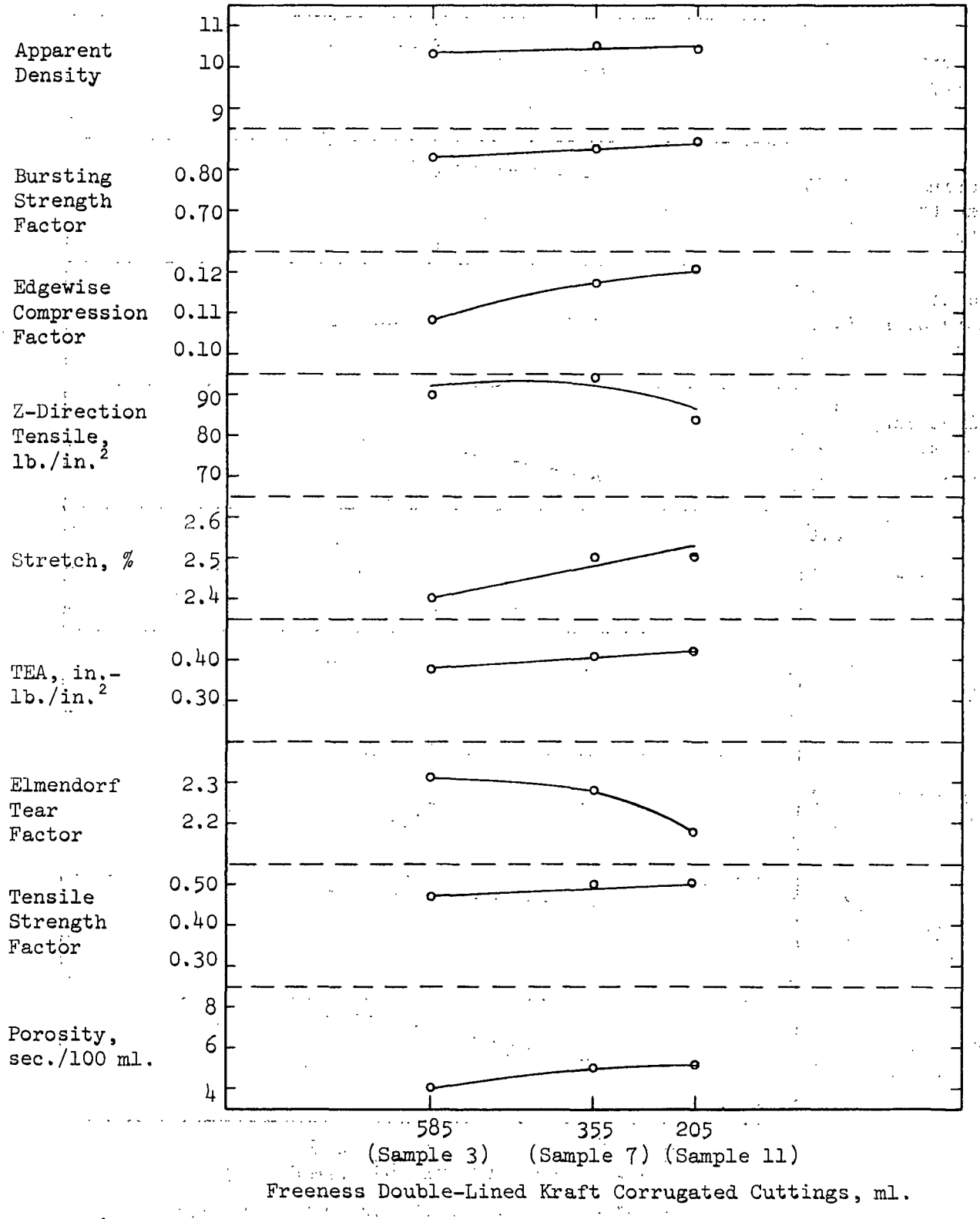

Figure 6. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With a Furnish of 90:10 Virgin Kraft (590-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings

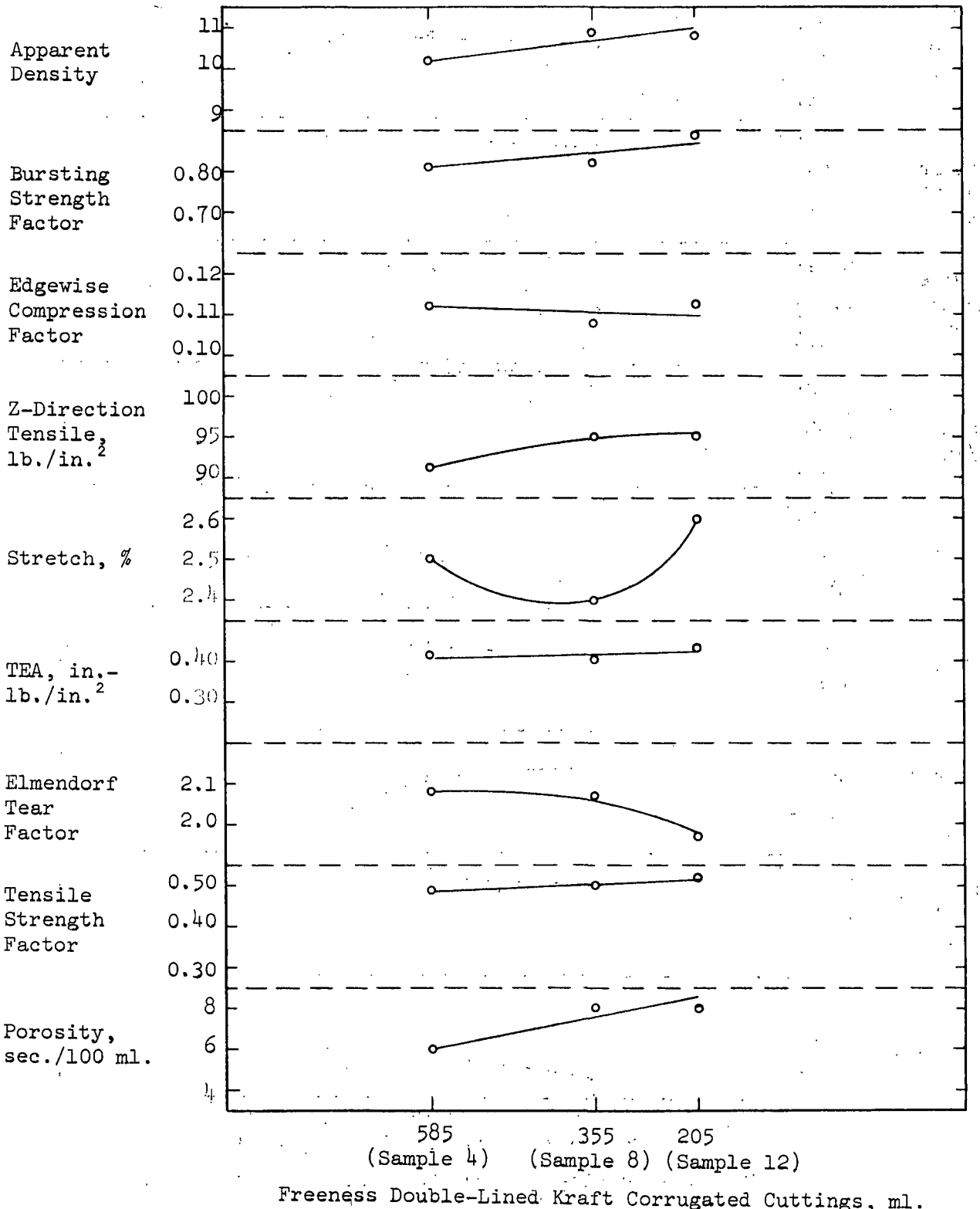

Figure 7. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With a Furnish of 80:20 Virgin Kraft (590-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings

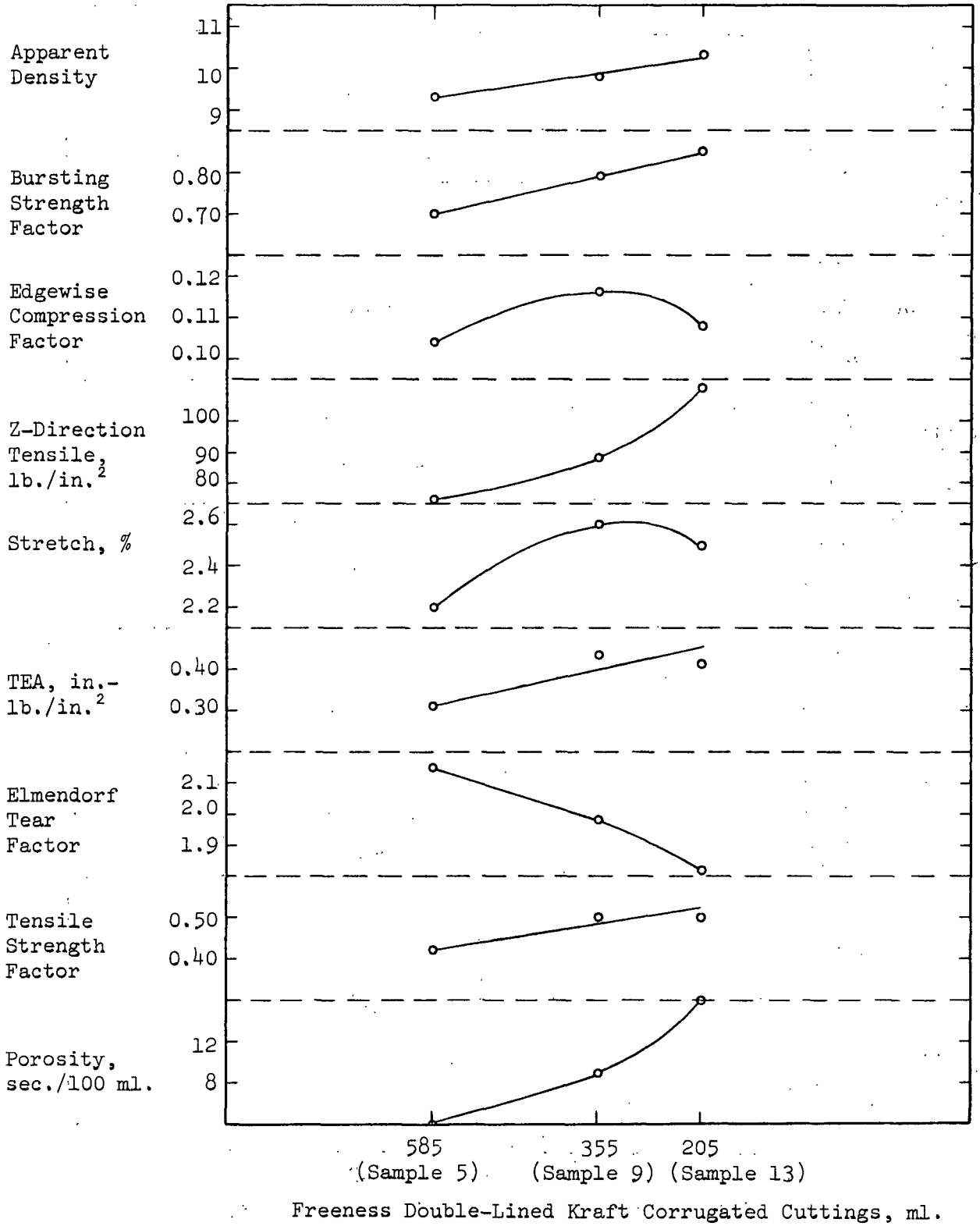

Figure 8. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With a Furnish of 60:40 Virgin Kraft (590-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings

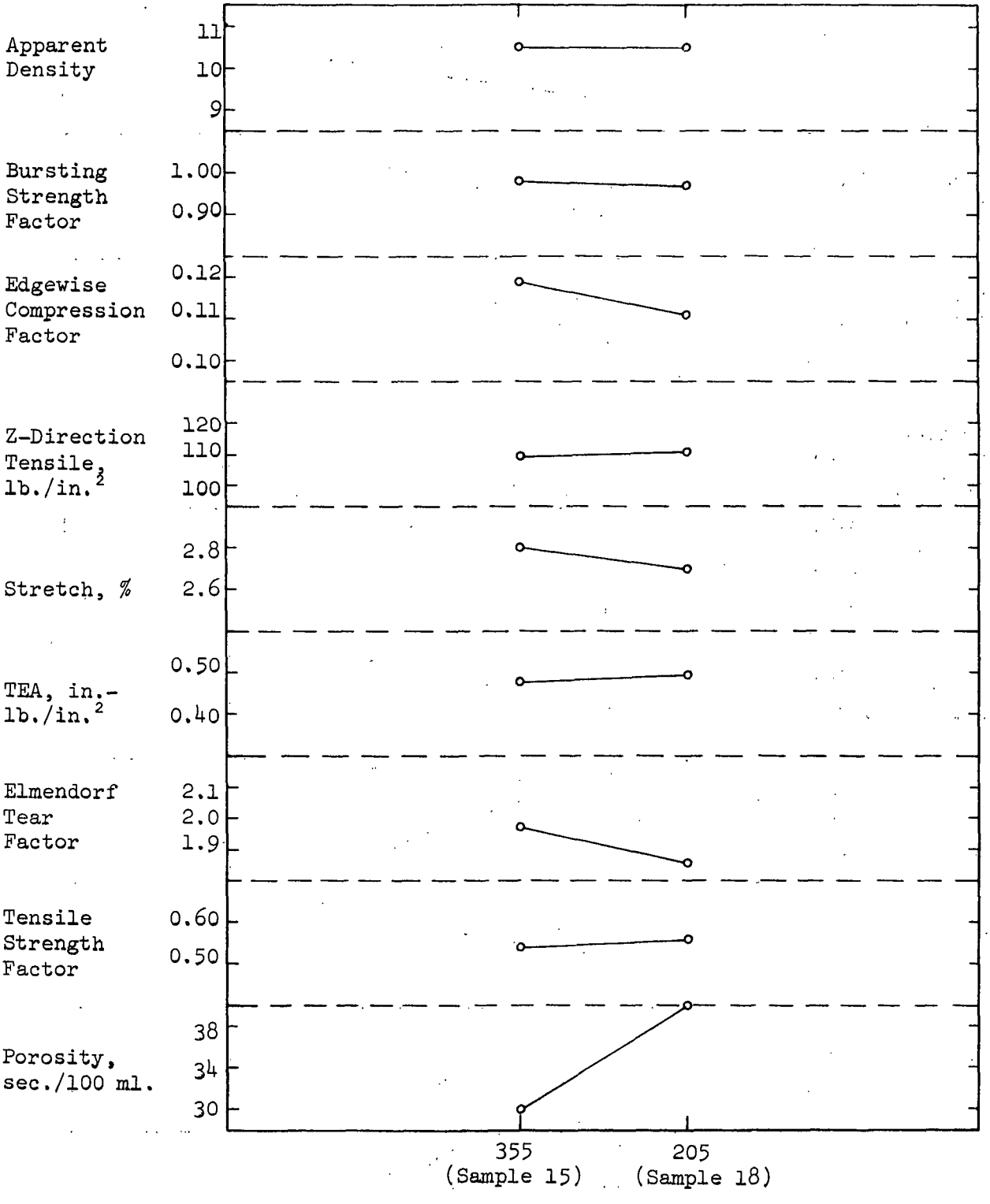

Figure 9. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With a Furnish of 90:10 Virgin Kraft (355-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings

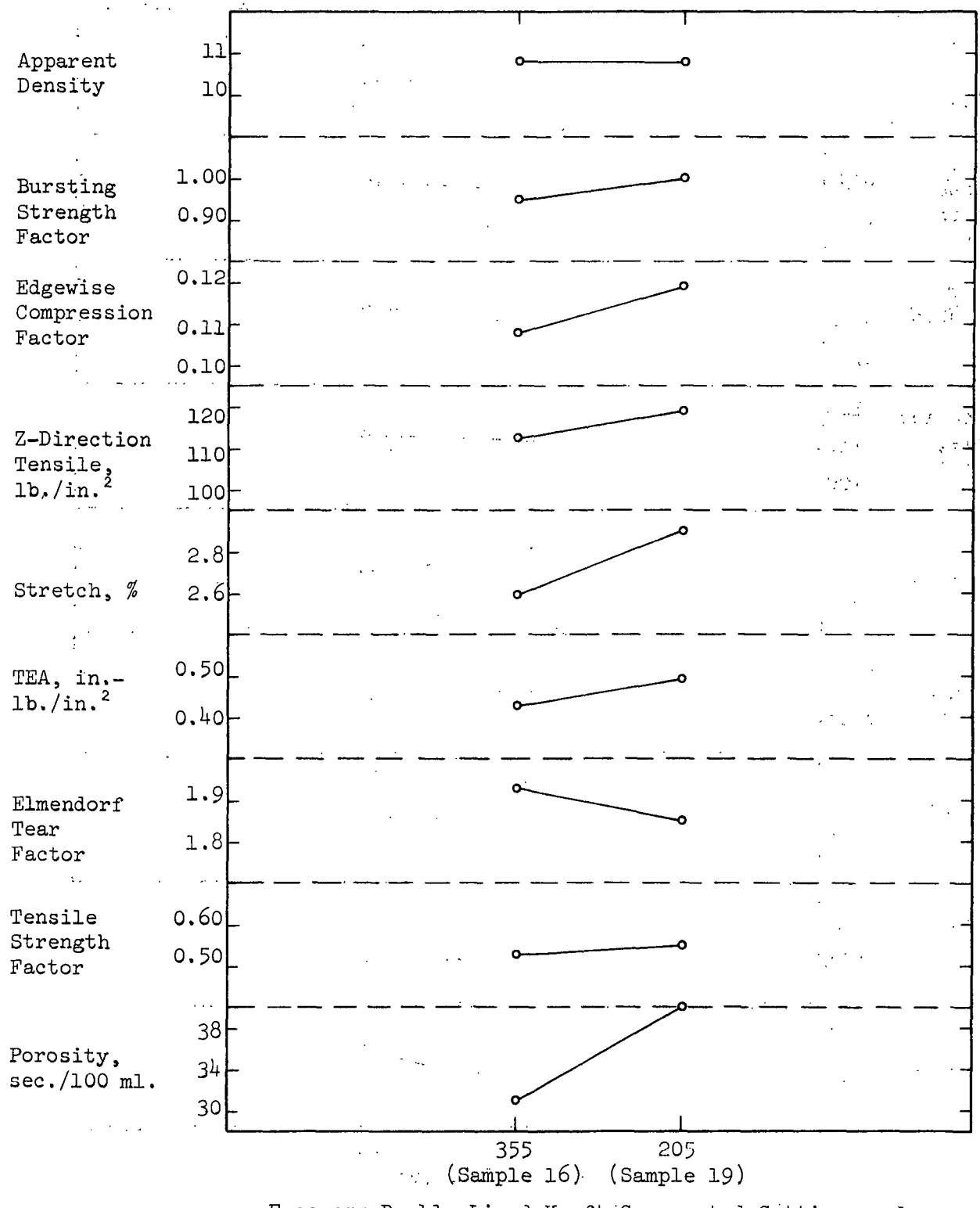

Figure 10. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With a Furnish of 80:20 Virgin Kraft (335-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings

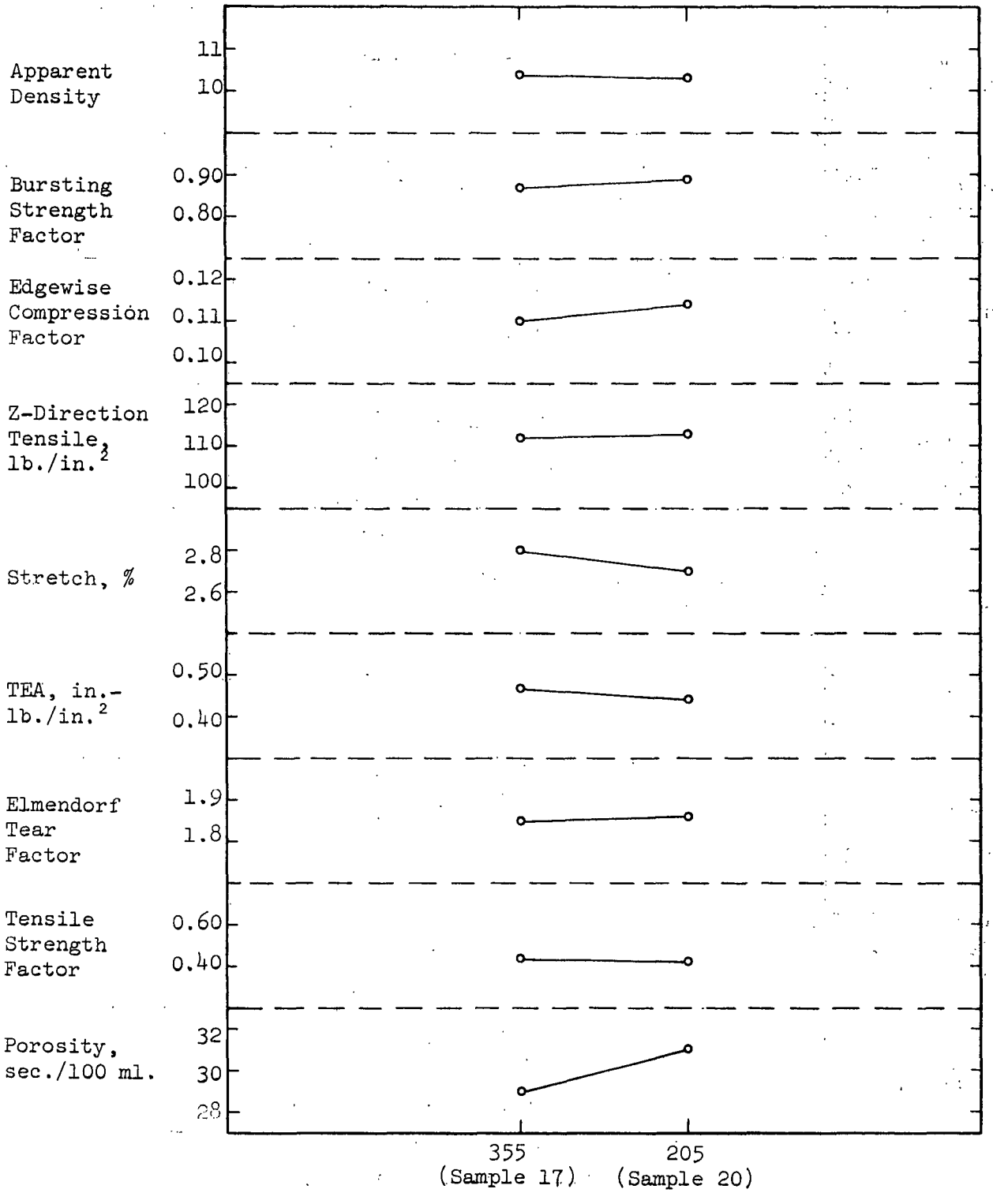

Figure 11. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With a Furnish of 60:40 Virgin Kraft (335-ml. Freeness) and Double-Lined Kraft Corrugated Cuttings

TABLE III

PHYSICAL PROPERTIES OF HANDSHEETS MADE WITH KRAFT PULP AND VARYING AMOUNTS OF CORRUGATED CONTAINER PAPER STOCK

Sample No.	Stock Characteristics: Furnish: Kraft Pulp Percent	Kraft Pulp Freeness	Paper Stock Percent	Paper Stock Freeness	Furnish Freeness, ml. C.S.	Drainage Time, sec.	Physical Properties of Handsheets: Basis Weight, 25 x 40-500, lb.	Caliper, pt.	Apparent Density	Diff. %	Bursting Strength: p.s.i.	Factor	Diff. %	Edgewise Compression: lb./in.	Factor	Diff. %
21	0	-	100	575	575	5.29	48.0	6.2	7.7	-33.0	22.1	0.46	-48.3	4.3	0.090	-21.7
2	100	590	0	-	585	4.95	47.2	4.1	11.5	-	41.9	0.89	-	5.5	0.115	-
22	90	590	10	575	590	4.92	46.4	4.7	9.9	-13.9	37.0	0.80	-10.1	4.8	0.102	-11.3
23	80	590	20	575	590	4.92	47.3	4.7	10.1	-12.2	37.8	0.80	-10.1	5.2	0.109	- 5.2
24	60	590	40	575	580	4.91	46.9	5.1	9.2	-20.0	33.6	0.72	-19.1	5.1	0.108	- 6.1
26	0	-	100	355	355	7.12	47.6	5.3	9.0	-21.7	32.6	0.69	-22.5	5.0	0.105	- 8.7
27	90	590	10	355	570	4.90	45.6	4.4	10.4	- 9.6	37.0	0.81	- 9.0	5.0	0.110	- 4.3
28	80	590	20	355	555	4.97	46.6	4.4	10.6	- 7.8	38.8	0.83	- 6.7	5.2	0.112	- 2.6
29	60	590	40	355	540	5.21	46.9	5.0	9.4	-18.4	37.0	0.79	-11.2	5.2	0.111	- 2.6
30	0	-	100	205	205	12.58	45.7	5.1	9.0	-21.7	33.0	0.72	-19.1	5.2	0.113	- 1.7
31	90	590	10	205	570	4.91	46.4	4.4	10.5	- 8.7	39.4	0.85	- 4.5	5.3	0.114	- 0.9
32	80	590	20	205	535	5.07	46.2	4.5	10.3	-10.4	40.7	0.88	- 1.1	5.1	0.109	- 5.2
33	60	590	40	205	455	5.51	46.3	4.8	9.6	-16.5	37.3	0.81	- 9.0	5.3	0.114	- 0.9
14	100	355	0	-	355	6.82	46.1	4.0	11.5	-	53.0	1.15	-	5.1	0.111	-
34	90	355	10	355	350	5.83	46.0	4.4	10.5	- 8.7	42.0	0.91	-20.9	5.7	0.124	+11.7
35	80	355	20	355	345	5.86	46.0	4.3	10.7	- 7.0	43.1	0.94	-18.3	5.1	0.110	- 0.9
36	60	355	40	355	350	6.02	46.2	4.6	10.0	-13.0	40.4	0.87	-24.3	5.4	0.116	+ 4.5
37	90	355	10	205	290	5.97	47.0	4.1	11.5	0.0	45.8	.97	-15.7	6.3	0.133	+19.9
38	80	355	20	205	275	6.13	47.2	4.6	10.3	-10.4	46.2	.98	-14.8	5.5	0.115	+ 3.6
39	60	355	40	205	240	7.05	47.6	4.7	10.1	-12.2	43.1	.91	-20.9	6.1	0.127	+14.4

TABLE III (Continued)

PHYSICAL PROPERTIES OF HANDSHEETS MADE WITH KRAFT PULP AND VARYING AMOUNTS OF CORRUGATED CONTAINER PAPER STOCK

Sample No.	Physical Properties of Handsheets													
	Elmendorf Tearing Resistance			Z-Direction Tensile		Porosity		Tensile Strength			Stretch		Tensile Energy Absorption	
	g./Sheet	Factor	Diff.%	lb./in.^{2}	Diff.%	Sec./100 ml.	Diff.%	lb./in.	Factor	Diff.%	%	Diff. %	in.-lb./in.^{2}	Diff. %
21	84	1.75	-17.5	60.6	-33.8	5	-28.6	14.4	0.300	-39.0	2.2	-15.4	0.227	-46.7
2	100	2.12	-	91.6	-	7	-	23.2	0.492	-	2.6	-	0.426	-
22	108	2.33	+ 9.9	84.4	- 7.9	4	-42.9	21.1	0.456	- 7.3	2.6	0.0	0.390	- 8.5
23	100	2.11	- 0.5	86.0	- 6.1	5	-28.6	22.2	0.470	- 4.5	2.3	-11.5	0.357	-16.2
24	102	2.18	- 2.8	78.6	-14.2	4	-42.9	20.4	0.436	-11.4	2.3	-11.5	0.327	-23.2
26	76	1.60	-24.5	97.8	+ 6.8	25	+257.1	19.4	0.408	-17.1	2.6	0.0	0.368	-13.6
27	98	2.15	- 1.4	88.8	- 3.1	4	-42.9	22.1	0.484	- 1.6	2.6	0.0	0.404	- 5.2
28	96	2.06	- 2.8	88.2	- 3.7	7	0.0	23.7	0.509	+ 3.7	2.6	0.0	0.421	- 1.2
29	96	2.05	- 3.3	91.6	0.0	9	+28.6	22.1	0.470	- 4.5	2.4	- 7.7	0.372	-12.7
30	62	1.36	-35.8	117.4	+27.8	102	+1357.1	21.6	0.472	- 4.1	2.6	0.0	0.385	- 9.6
31	96	2.07	- 2.4	95.8	+ 4.6	7	0.0	22.6	0.487	- 1.0	2.6	0.0	0.416	- 2.3
32	89	1.93	- 9.0	98.0	+ 7.0	10	+42.9	22.9	0.496	+ 0.8	2.6	0.0	0.407	- 4.5
33	85	1.84	-13.2	103.2	+12.7	20	+185.7	22.0	0.476	- 3.3	2.6	0.0	0.411	- 3.8
14	84	1.82	-	128.6	-	46	-	26.5	0.575	-	3.0	-	0.559	-
34	90	1.96	+ 7.7	116.8	- 9.2	39	-18.0	24.2	0.526	- 8.5	3.0	0.0	0.511	- 8.6
35	88	1.91	+ 4.9	114.6	-10.9	32	-30.4	23.9	0.519	- 9.7	3.0	0.0	0.507	- 9.3
36	88	1.91	+ 4.9	111.0	-21.5	33	-28.3	23.0	0.498	-13.4	3.0	0.0	0.497	-11.1
37	88	1.87	+ 2.7	116.8	- 9.2	51	+10.9	26.0	0.552	- 4.0	3.0	0.0	0.552	- 1.3
38	92	1.95	+ 7.4	118.8	- 7.6	47	+ 2.2	25.2	0.533	- 7.3	3.1	+ 3.3	0.549	- 1.8
39	83	1.74	- 4.4	121.6	- 5.4	53	+15.2	24.9	0.523	- 9.0	3.0	0.0	0.536	- 4.1

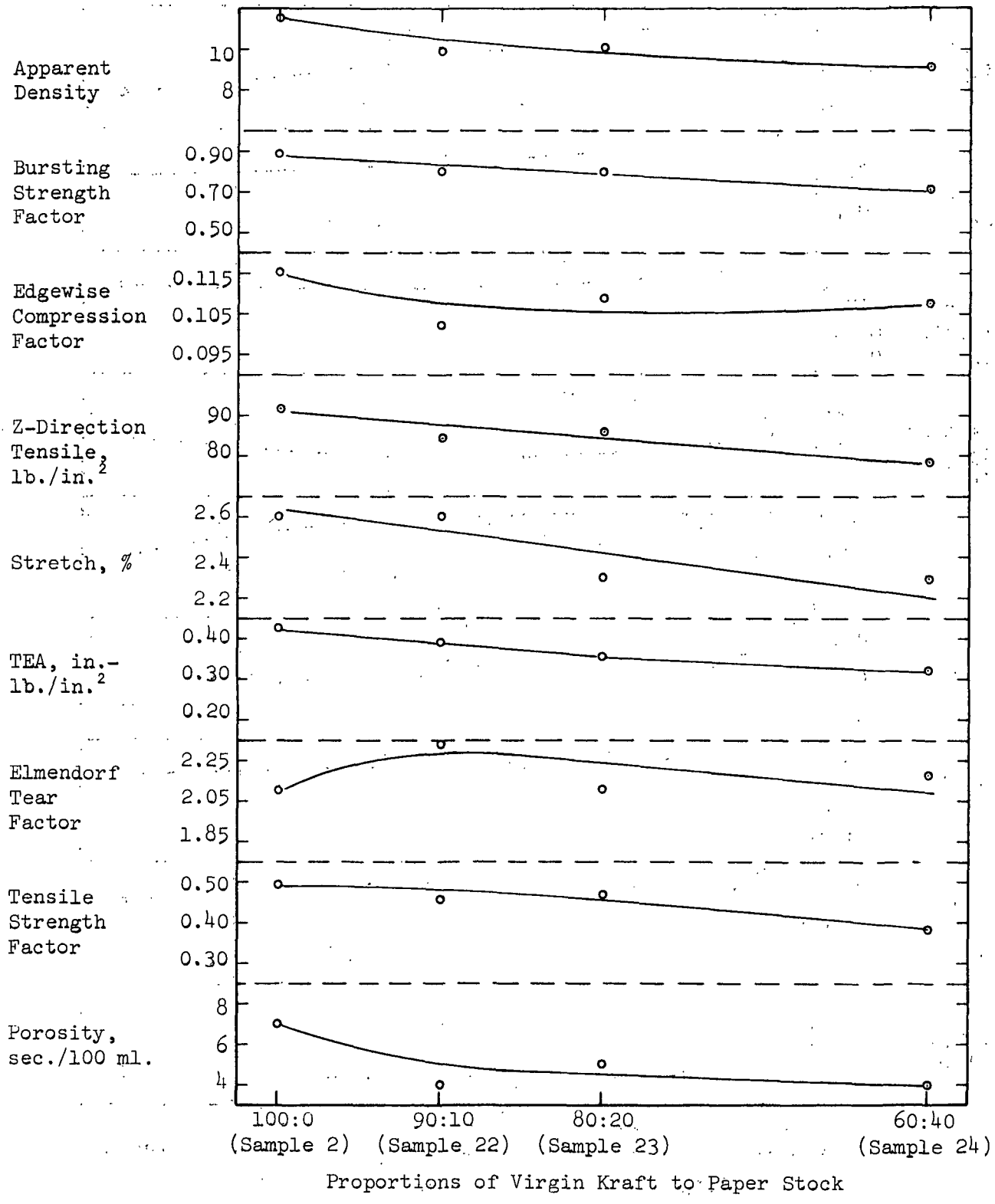

Figure 12. Effect of Varying Proportions of Virgin Kraft (590-ml. Freeness) and Corrugated Container Stock (575-ml. Freeness) on Sheet Strength

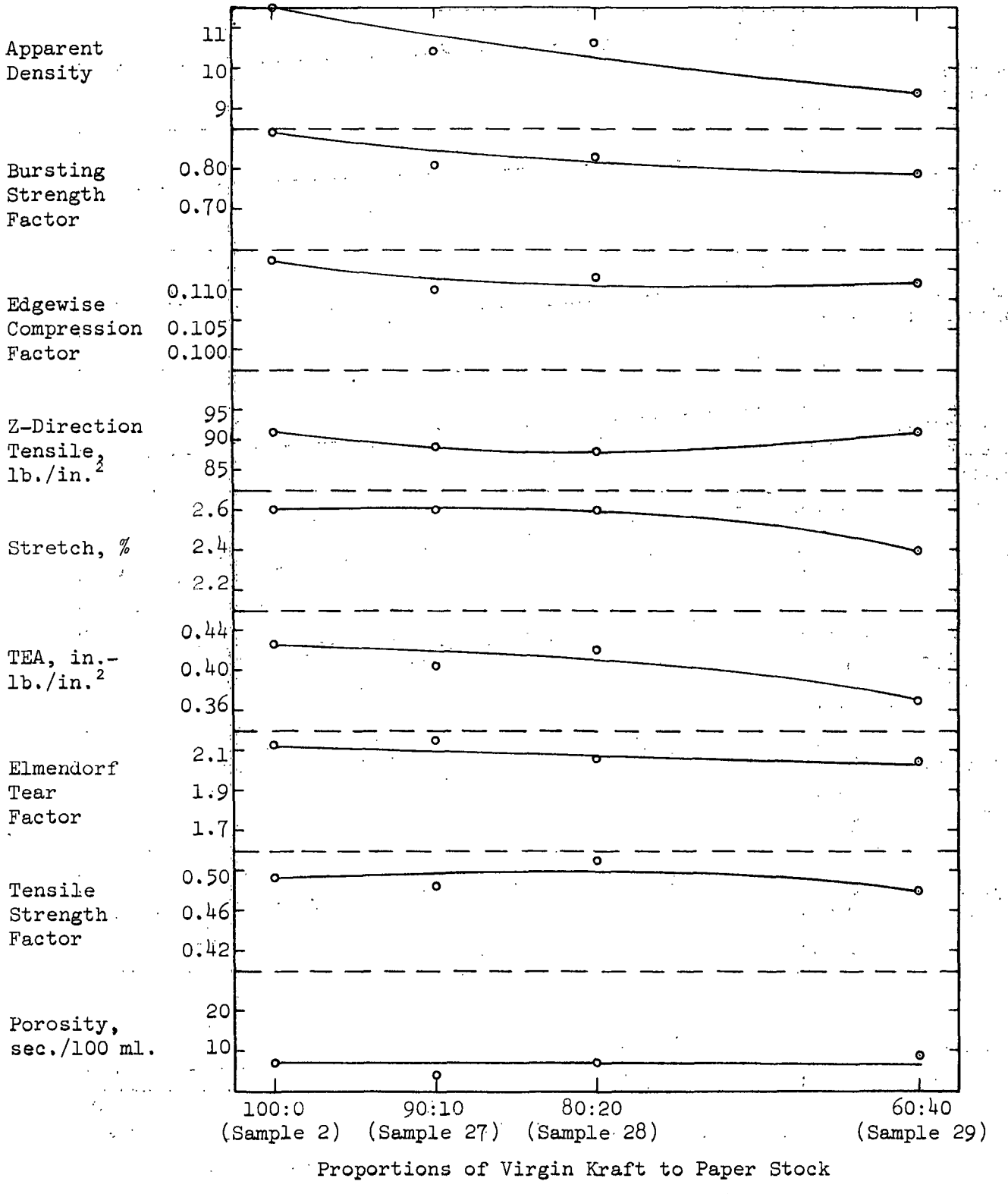

Figure 13. Effect of Varying Proportions of Virgin Kraft (590-ml. Freeness) and Corrugated Container Stock (355-ml. Freeness) on Sheet Strength

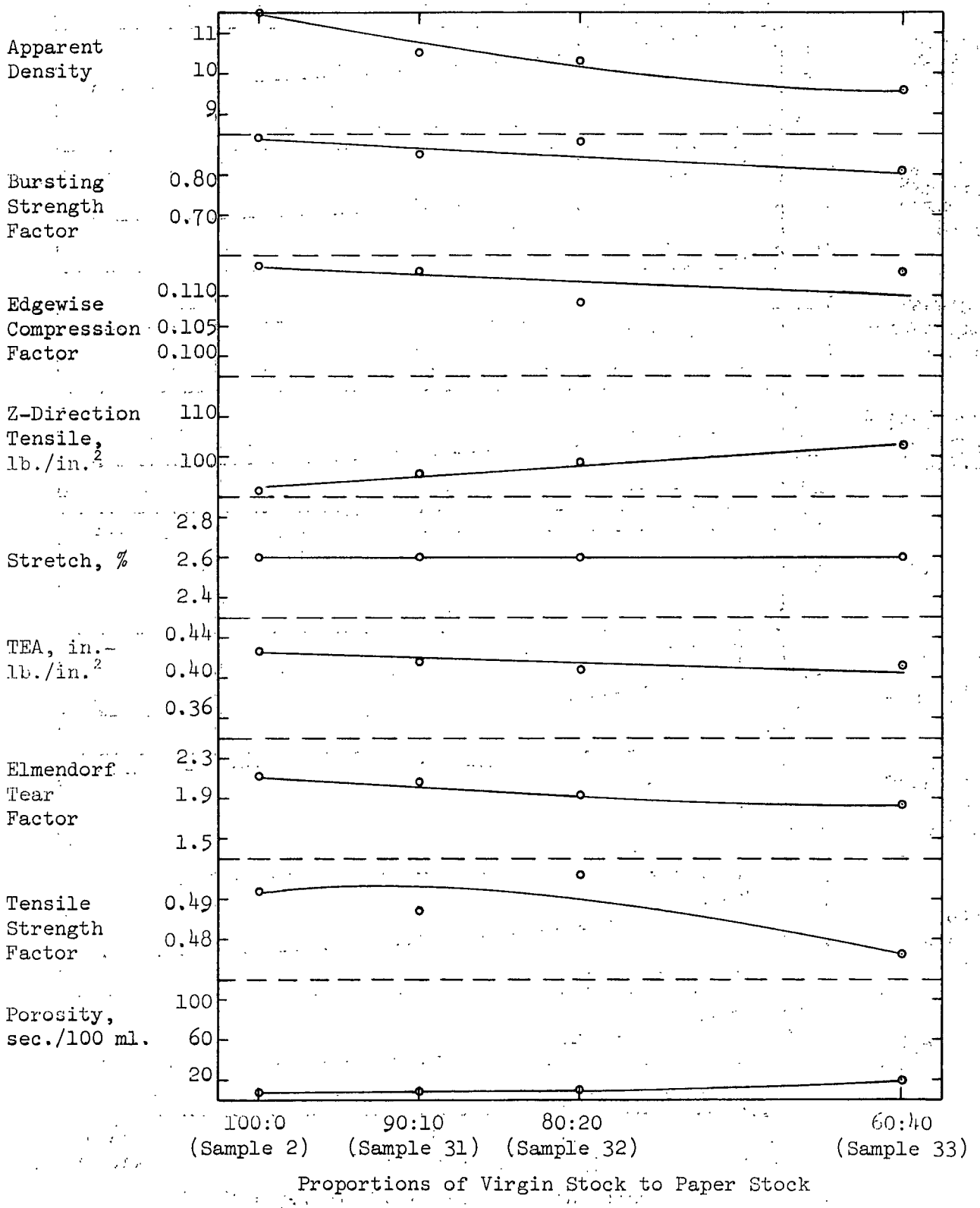

Figure 14. Effect of Varying Proportions of Virgin Kraft (590-ml. Freeness) and Corrugated Container Stock (205-ml. Freeness) on Sheet Strength

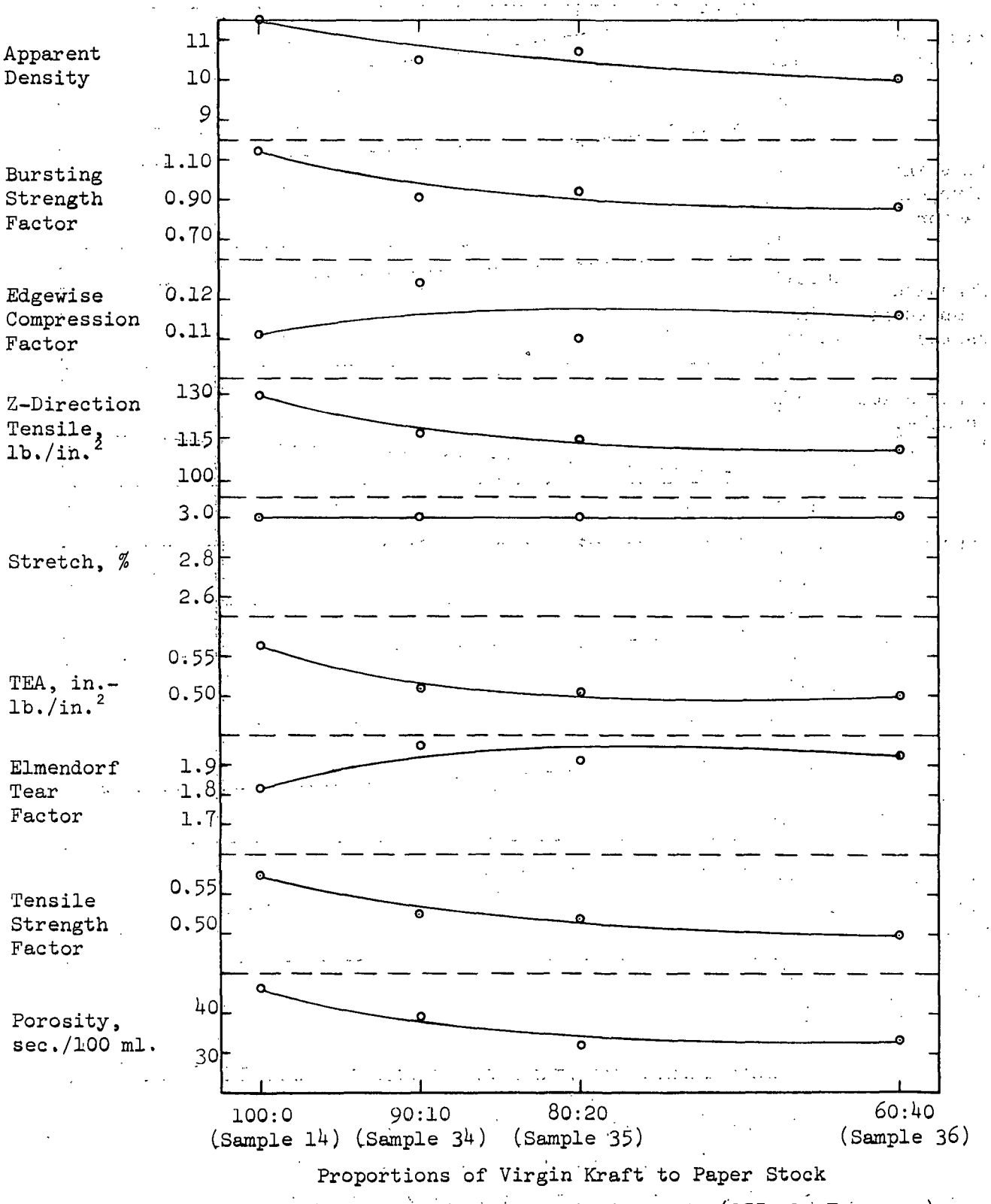

Figure 15. Effect of Varying Proportions of Virgin Kraft (355-ml. Freeness) and Corrugated Container Stock (355-ml. Freeness) on Sheet Strength

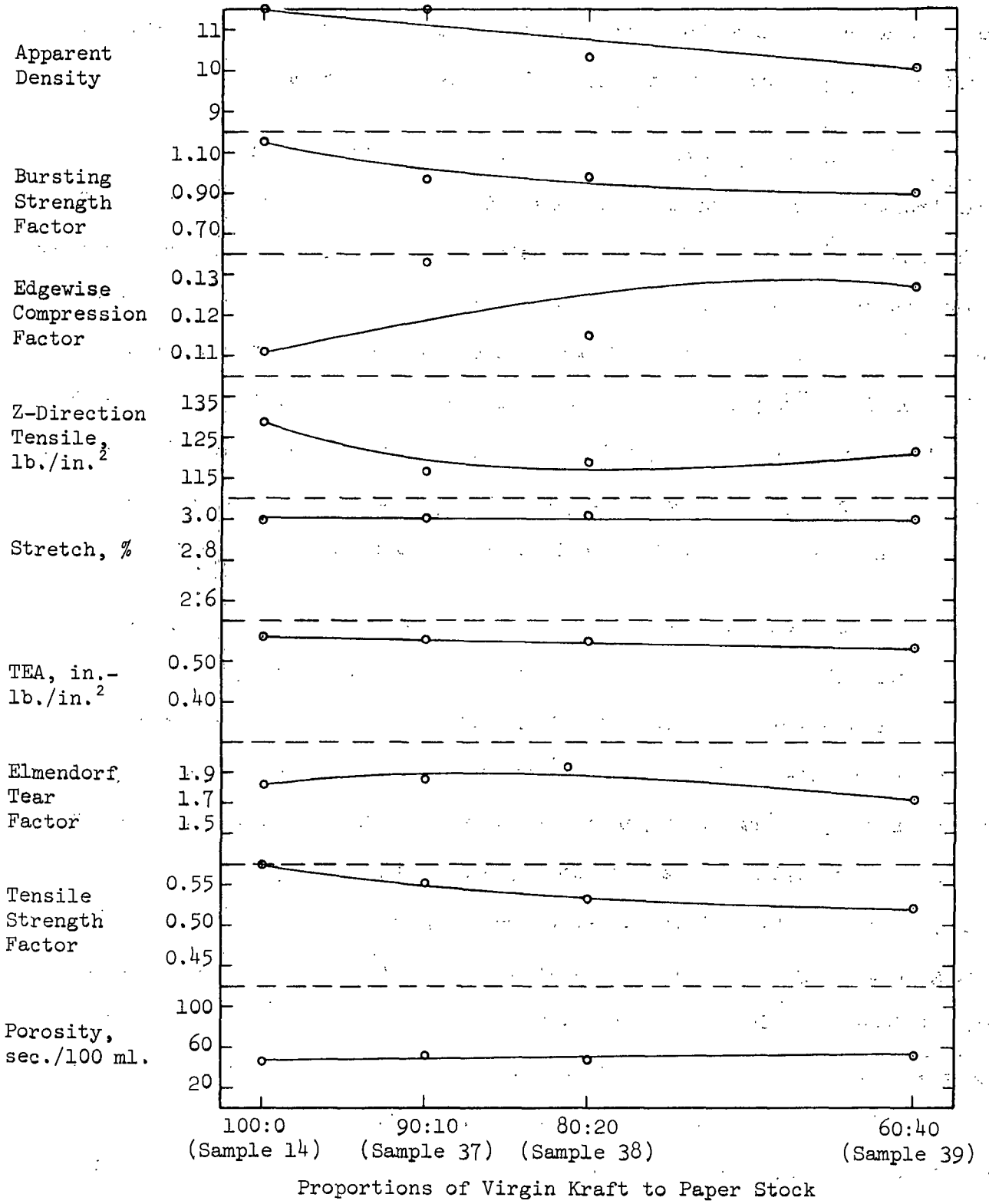

Figure 16. Effect of Varying Proportions of Virgin Kraft (355-ml. Freeness) and Corrugated Container Stock (205-ml. Freeness) on Sheet Strength

in contrast, remained essentially constant. Tearing strength of the 590/575 handsheet passed through a maximum whereas it decreased slightly with increase in the percentage of paper stock for the 590/355 and 590/205 handsheets.

When the corresponding results for the handsheets made from a furnish of virgin kraft refined to 355-ml. freeness and paper stock refined to 355 and 205-ml. freeness (see Fig. 9 and 10) are considered, it should be noted that apparent density, bursting strength, Z-direction tensile, and tensile strength decreased with increase in the percentage of paper stock content. Tearing strength of the 355/355 furnish exhibited a maximum whereas the 355/205 furnish remained essentially constant. Tensile energy absorption of the 355/355-ml. furnish decreased whereas the 355/205 furnish did not appear to be significantly influenced by the amount of paper stock. Porosity remained unchanged or decreased slightly.

As in the case of the double-lined kraft corrugated cutting stock, bursting strength decreased with increase in the percentage of paper stock in the furnish regardless of the level of refining of the paper stock. However, as may be seen in Fig. 17-22, the lower the freeness of the paper stock the less the loss in bursting strength. Figures 17-19 show that for the furnishes consisting of virgin kraft (590-ml. freeness) and 90:10, 80:20, and 60:40 ratios of paper stock refined to 575, 355, and 205-ml. freeness, all test properties except tearing strength generally increased with the degree of refining measured in terms of freeness. Tearing strength, as would be expected, decreased with the degree of refining. The corresponding results for the furnish consisting of virgin kraft (355-ml. freeness) and paper stock refined to 355 and 205 ml. are shown in Fig. 20-22. As in the case of the furnishes with the 590-ml. kraft, the general trend is for the test properties to increase with increase in refining; however, the tearing strength, Z-direction tensile, and stretch do not appear to be very sensitive to the degree of refining of the paper stock.

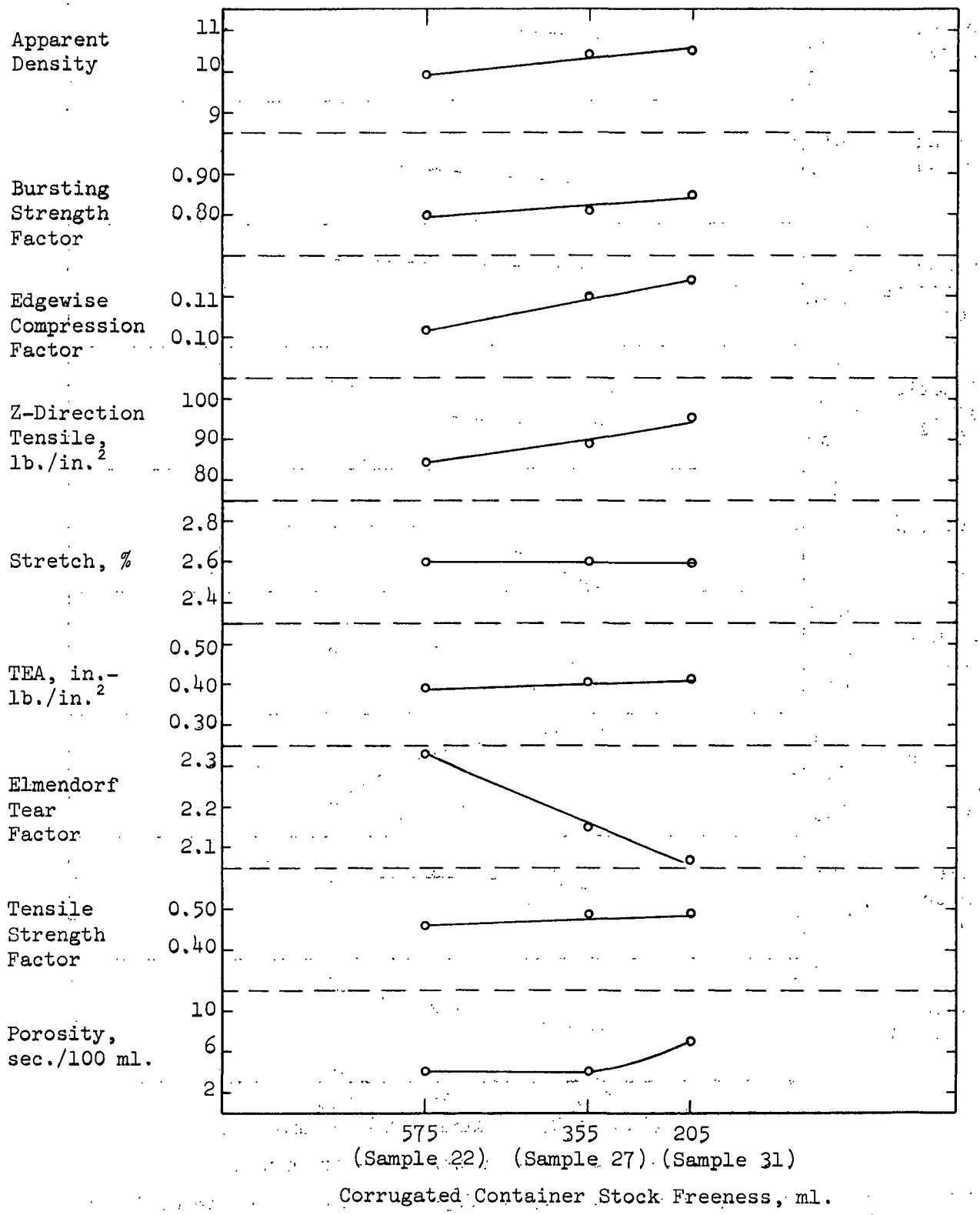

Figure 17. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With Furnish of 90:10 Virgin Kraft (590-ml. Freeness) and Corrugated Container Stock

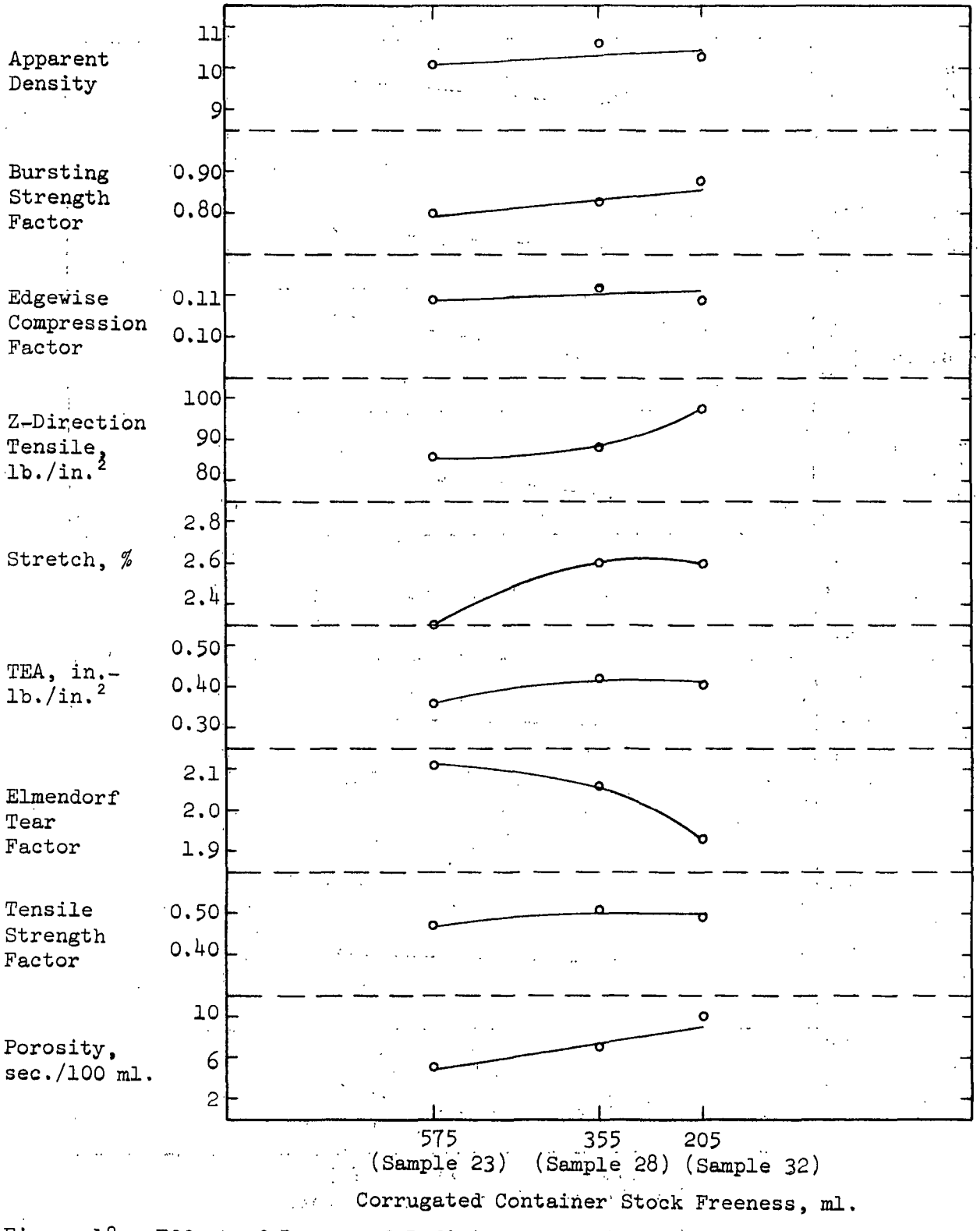

Figure 18. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With Furnish of 80:20 Virgin Kraft (590-ml. Freeness) and Corrugated Container Stock

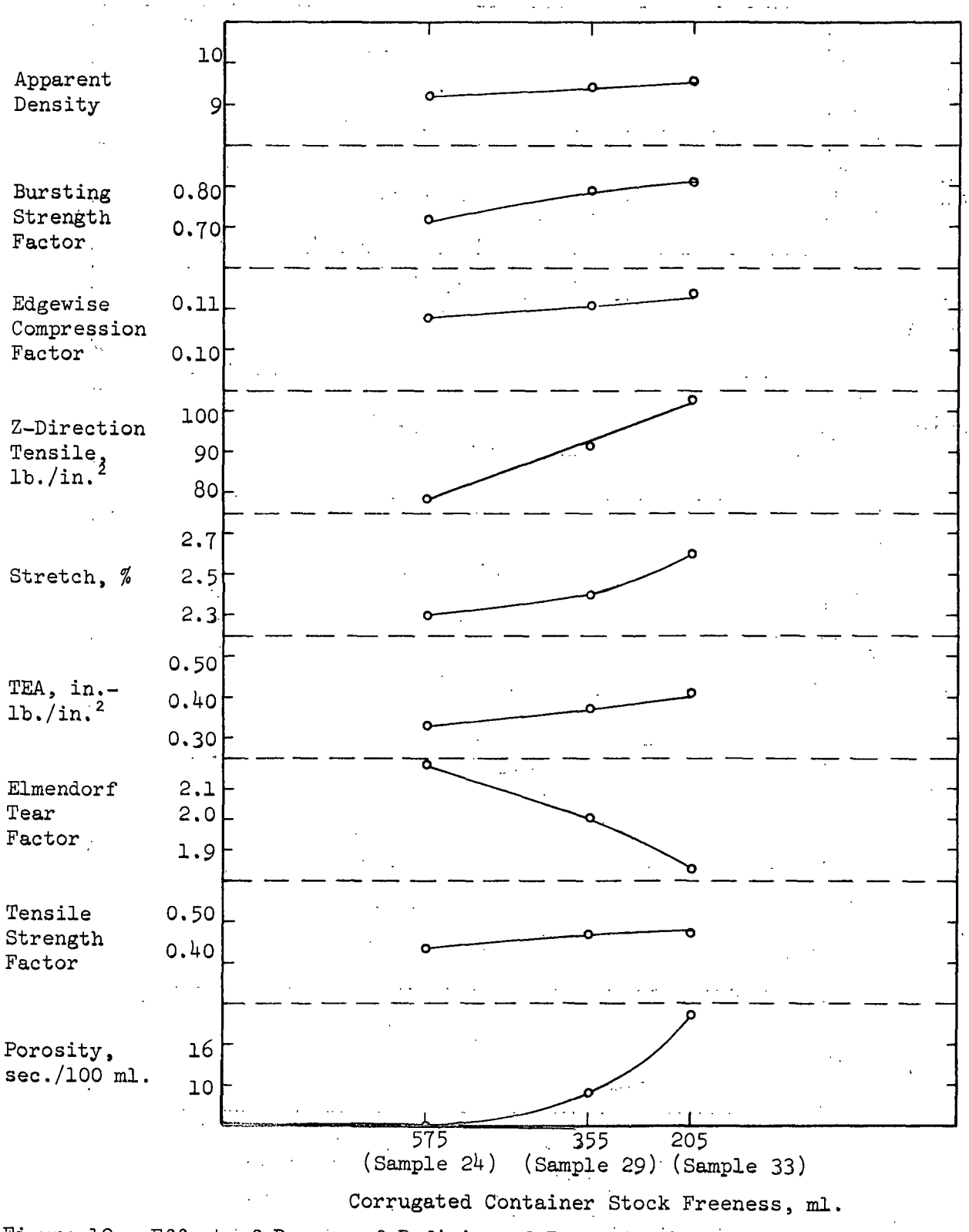

Figure 19. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With Furnish of 60:40 Virgin Kraft (590-ml. Freeness) and Corrugated Container Stock

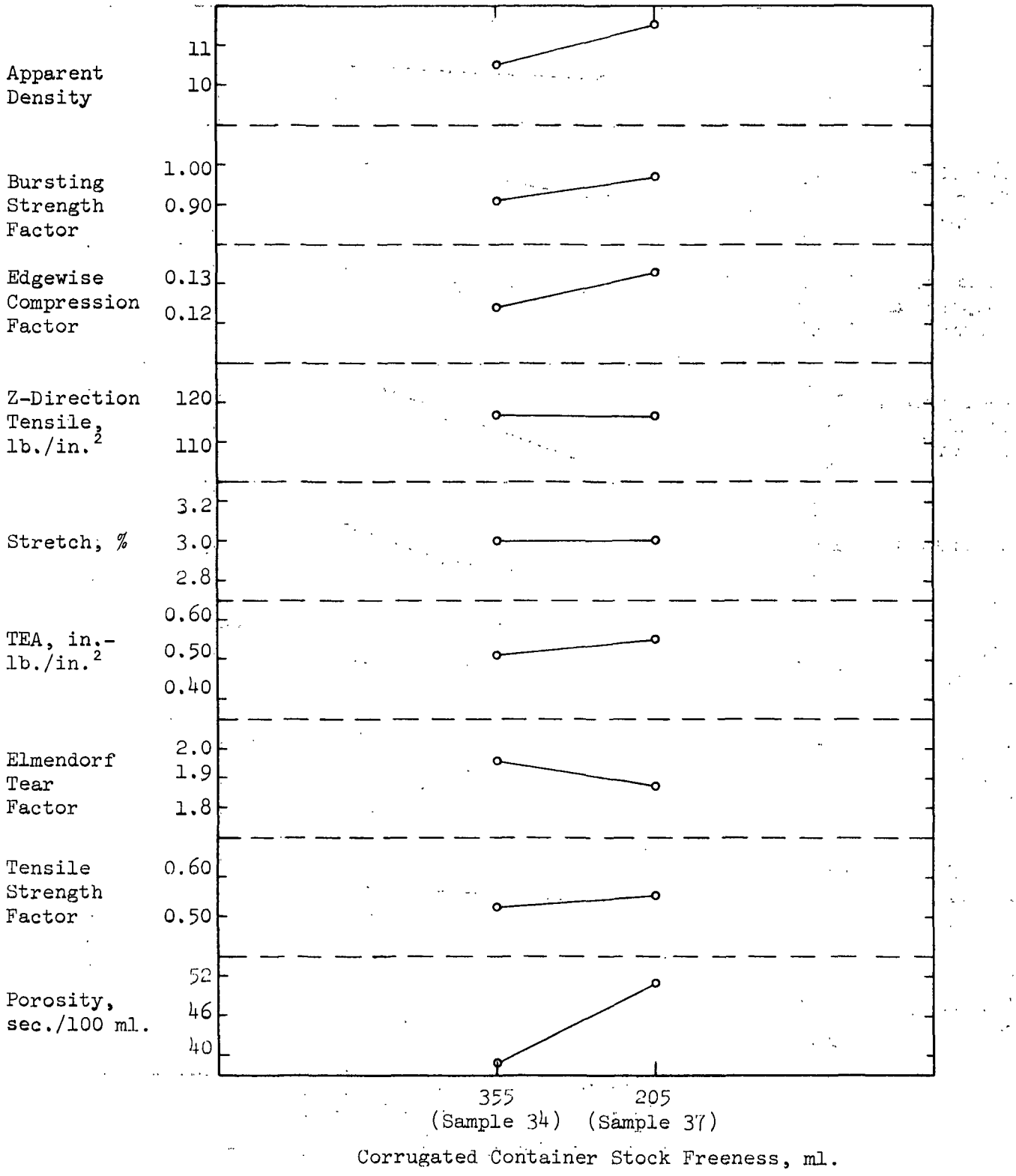

Figure 20. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With Furnish of 90:10 Virgin Kraft (355-ml. Freeness) and Corrugated Container Stock

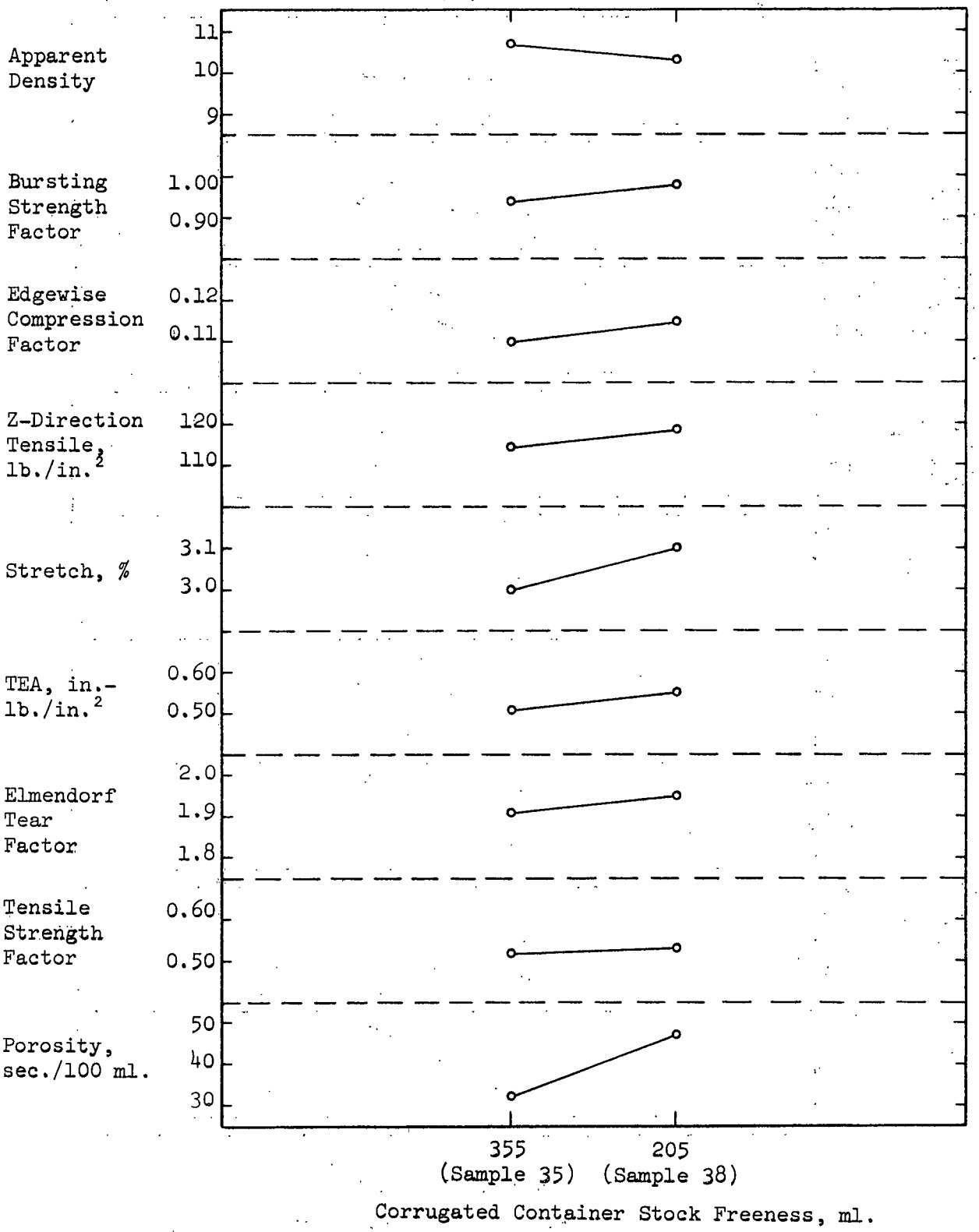

Figure 21. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With Furnish of 80:20 Virgin Kraft (355-ml. Freeness) and Corrugated Container Stock

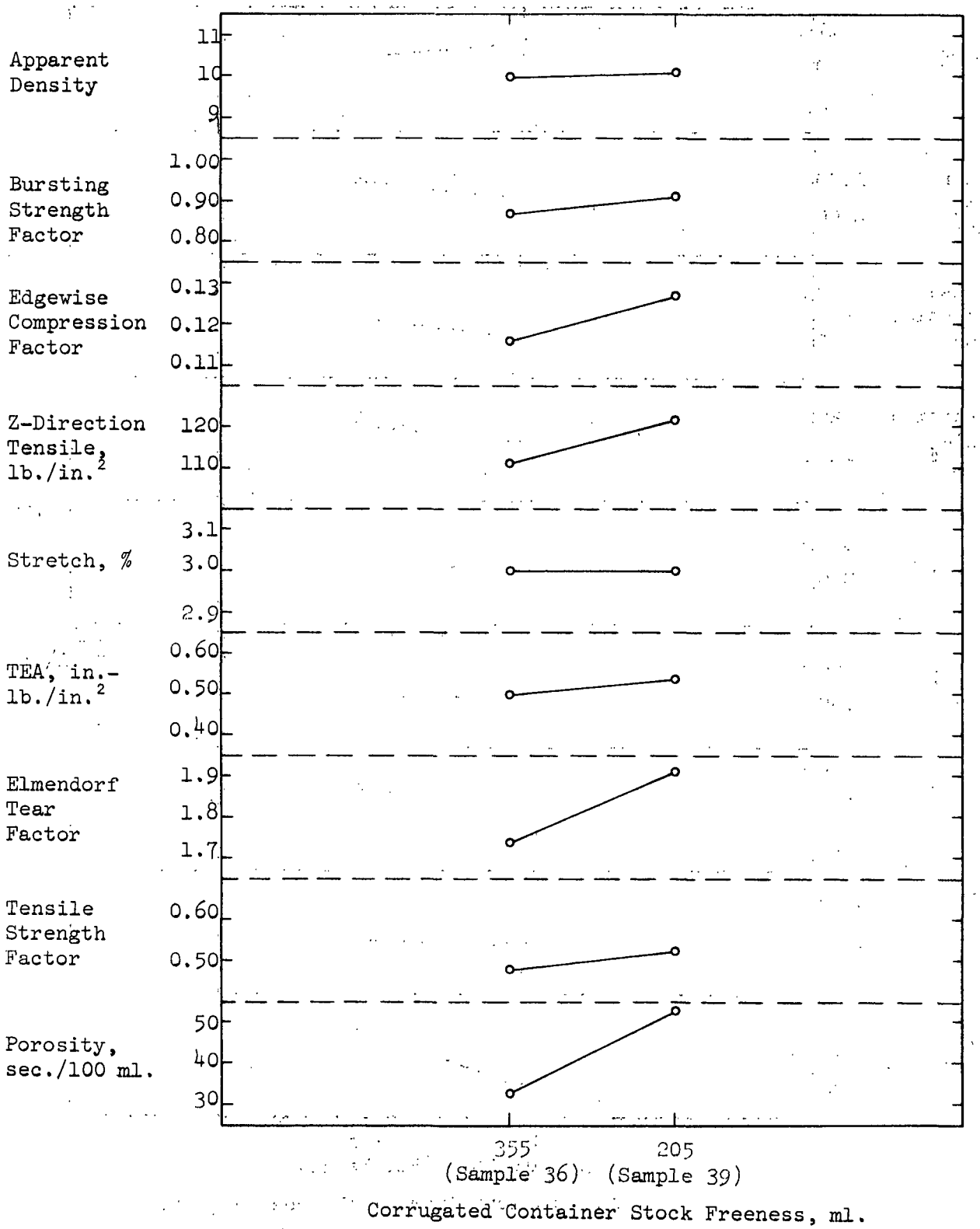

Figure 22. Effect of Degree of Refining of Paper Stock on Strength of Sheet Made With Furnish of 60:40 Virgin Kraft (355-ml. Freeness) and Corrugated Container Stock

In order to obtain a better insight into the effect of varying the amount of paper stock in kraft linerboard furnishes on such properties as bursting strength, tensile strength, edgewise compression, and tearing strength, the results tabulated in Tables II and III have been analyzed statistically by means of linear regression analysis. The results obtained for bursting strength as the result of varying the paper stock in the furnish from 0 to 40% are summarized in Table IV and illustrated in Fig. 23-29. It may be seen in Fig. 23 that in all cases the bursting strength decreased as the percentage of double-lined kraft corrugated cutting increased. In the case of the furnish consisting of kraft pulp at 590-ml. freeness, bursting strength decreased most rapidly when the percentage of high freeness (585 ml.) paper stock was increased and slowest when the percentage of low freeness (205 ml.) paper stock was increased. The results of the 590/355 furnish was about intermediate between the other two furnishes.

In the case of the 355-ml. freeness kraft pulp furnish the decrease in bursting strength exhibited by the 355/355 freeness furnish was only slightly greater than for the 355/205-ml. freeness furnish.

The corresponding relationships for the furnishes containing corrugated container as the paper stock additive are shown in Fig. 24. As in the case of the double-lined kraft corrugated cuttings, the decrease in bursting strength for the 590-ml. freeness kraft furnish with increase in paper stock was greatest when the paper stock was refined to 575-ml. freeness and least when refined to 205-ml. freeness. The same general trend may be noted for the kraft furnish refined to 355 ml.

A comparison of the relationships between bursting strength and percentage of paper stock in the furnish for the two grades of paper stock — i.e.,

TABLE IV

RELATIONSHIP BETWEEN BURSTING STRENGTH AND PERCENTAGE OF PAPER STOCK IN THE FURNISH

Type Furnish	Freeness, ml. Kraft Pulp	Freeness, ml. Paper Stock	Regression Equation[a]	Correlation Coefficient
Kraft pulp-double-lined kraft cutting	590	585	$Y = -0.0046X + 0.888$	-0.990
Kraft pulp-corrugated container stock	590	575	$Y = -0.0039X + 0.870$	-0.948
Kraft pulp-double-lined cutting	590	355	$Y = -0.0024X + 0.880$	-0.971
Kraft pulp-corrugated container stock	590	355	$Y = -0.0021X + 0.886$	-0.813
Kraft pulp-double-lined cutting	590	205	$Y = -0.00086X + 0.890$	-0.764
Kraft pulp-corrugated container stock	590	205	$Y = -0.0017X + 0.888$	-0.828
Kraft pulp-double-lined cutting	355	355	$Y = -0.0063X + 1.098$	-0.915
Kraft pulp-corrugated container stock	355	355	$Y = -0.0057X + 1.068$	-0.785
Kraft pulp-double-lined cutting	355	205	$Y = -0.0053X + 1.098$	-0.861
Kraft pulp-corrugated container stock	355	205	$Y = -0.0051X + 1.092$	-0.847

[a] Y = Bursting strength factor.

X = Percentage of paper stock.

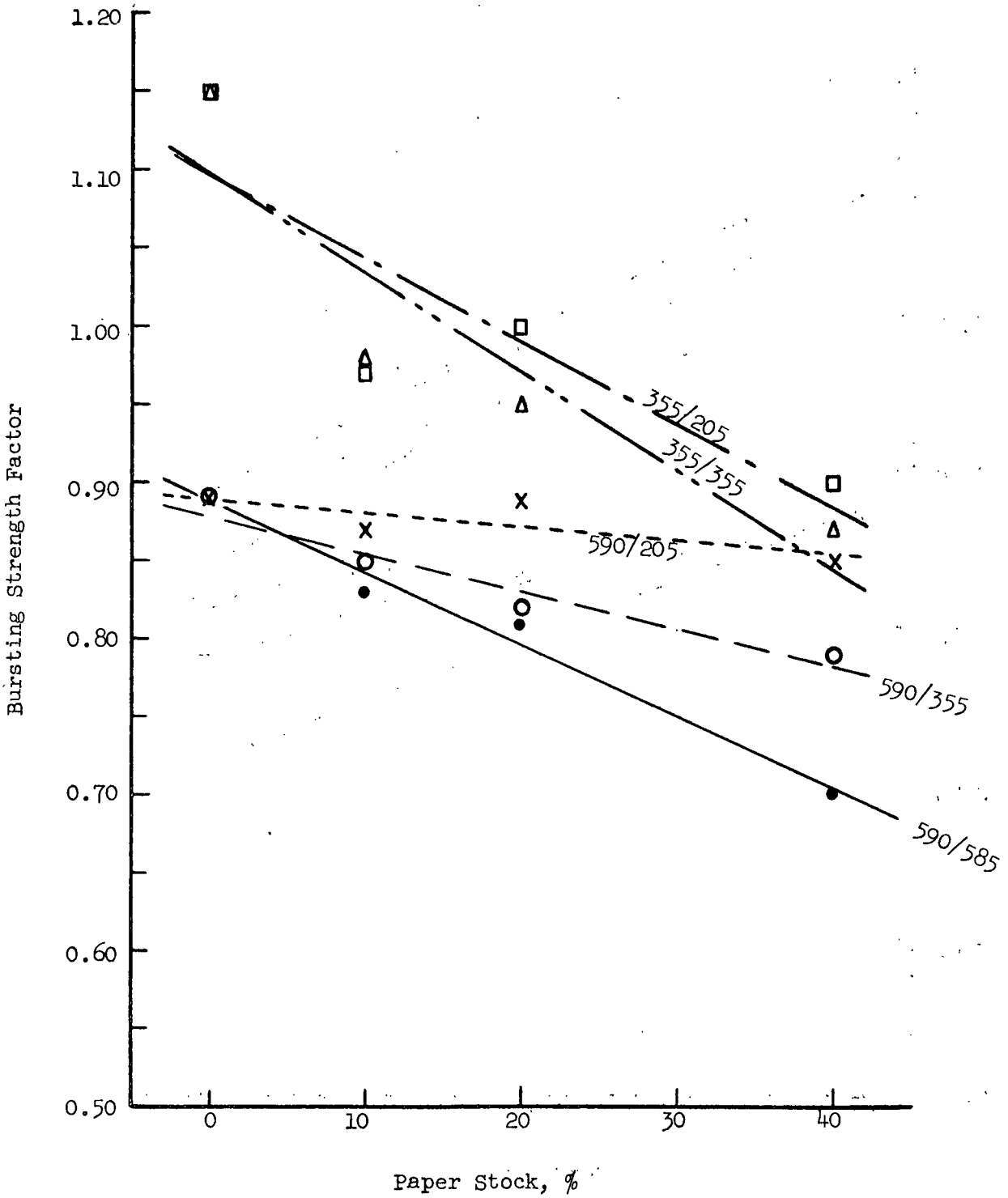

Figure 23. Relationship Between Bursting Strength and Percentage of Double-Lined Kraft Corrugated Cuttings in Furnish

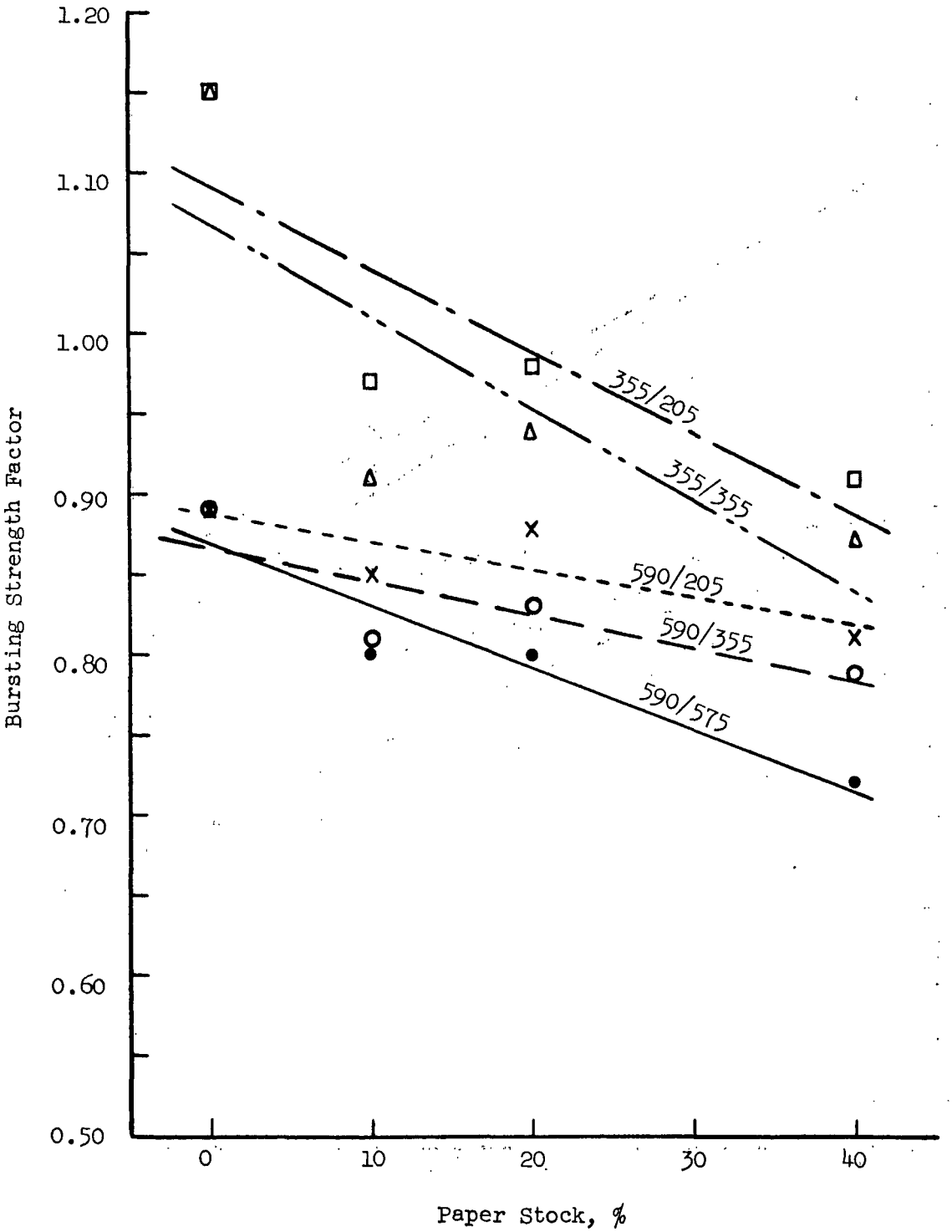

Figure 24. Relationship Between Bursting Strength and Percentage of Corrugated Container Stock in the Furnish

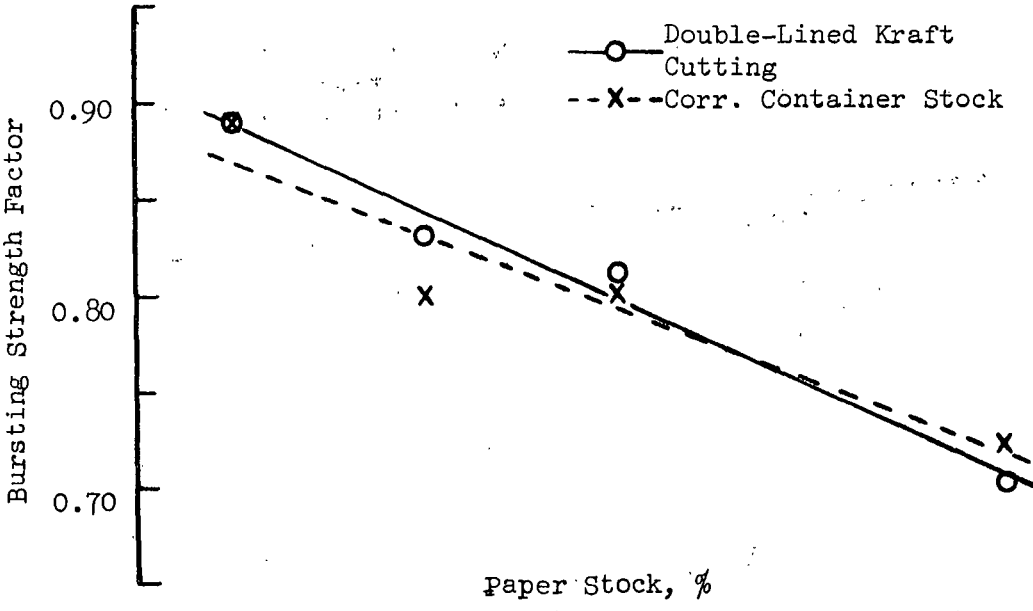

Figure 25. Comparison of Relationship Between Bursting Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/585-575)

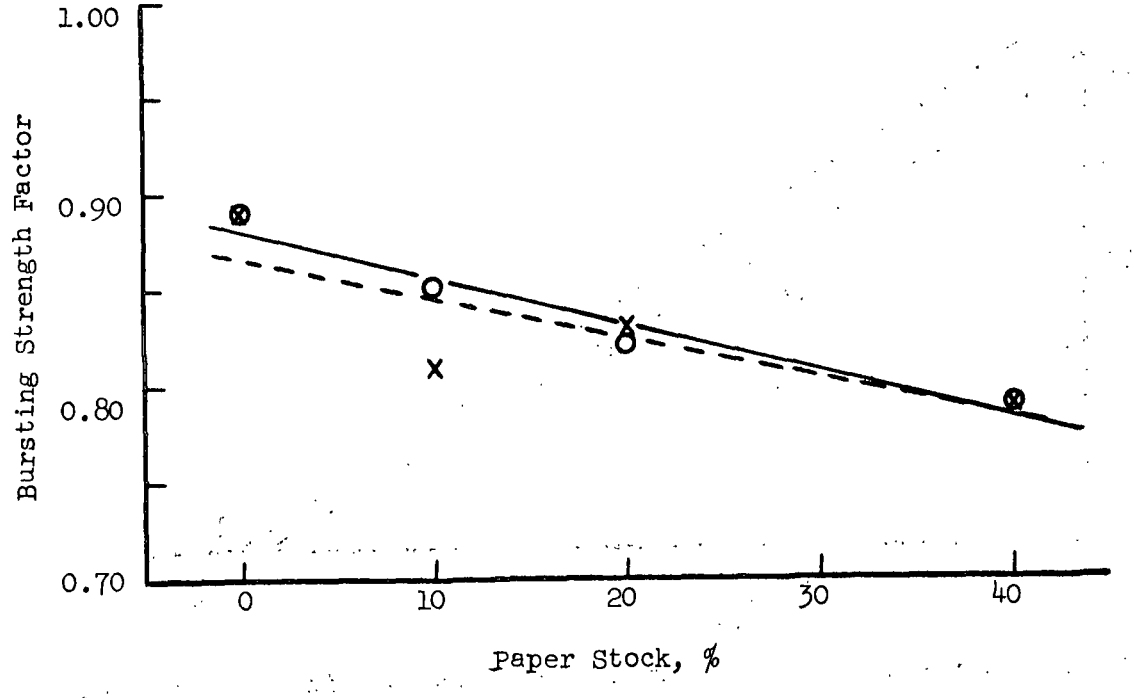

Figure 26. Comparison of Relationship Between Bursting Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 595/355)

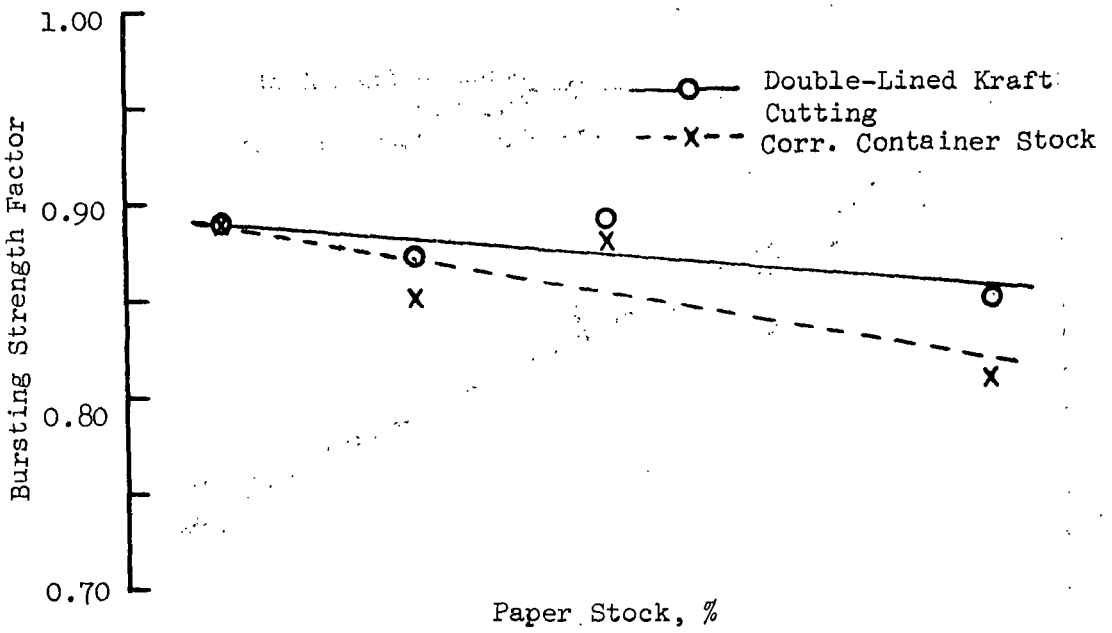

Figure 27. Comparison of Relationship Between Bursting Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/205)

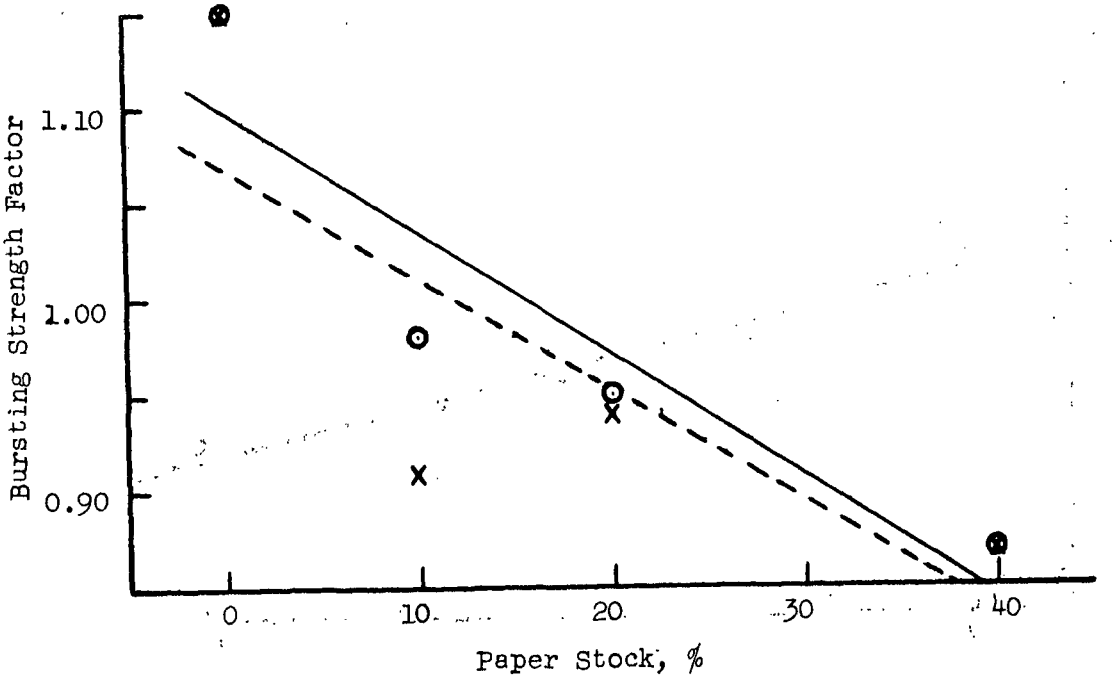

Figure 28. Comparison of Relationship Between Bursting Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 355/355)

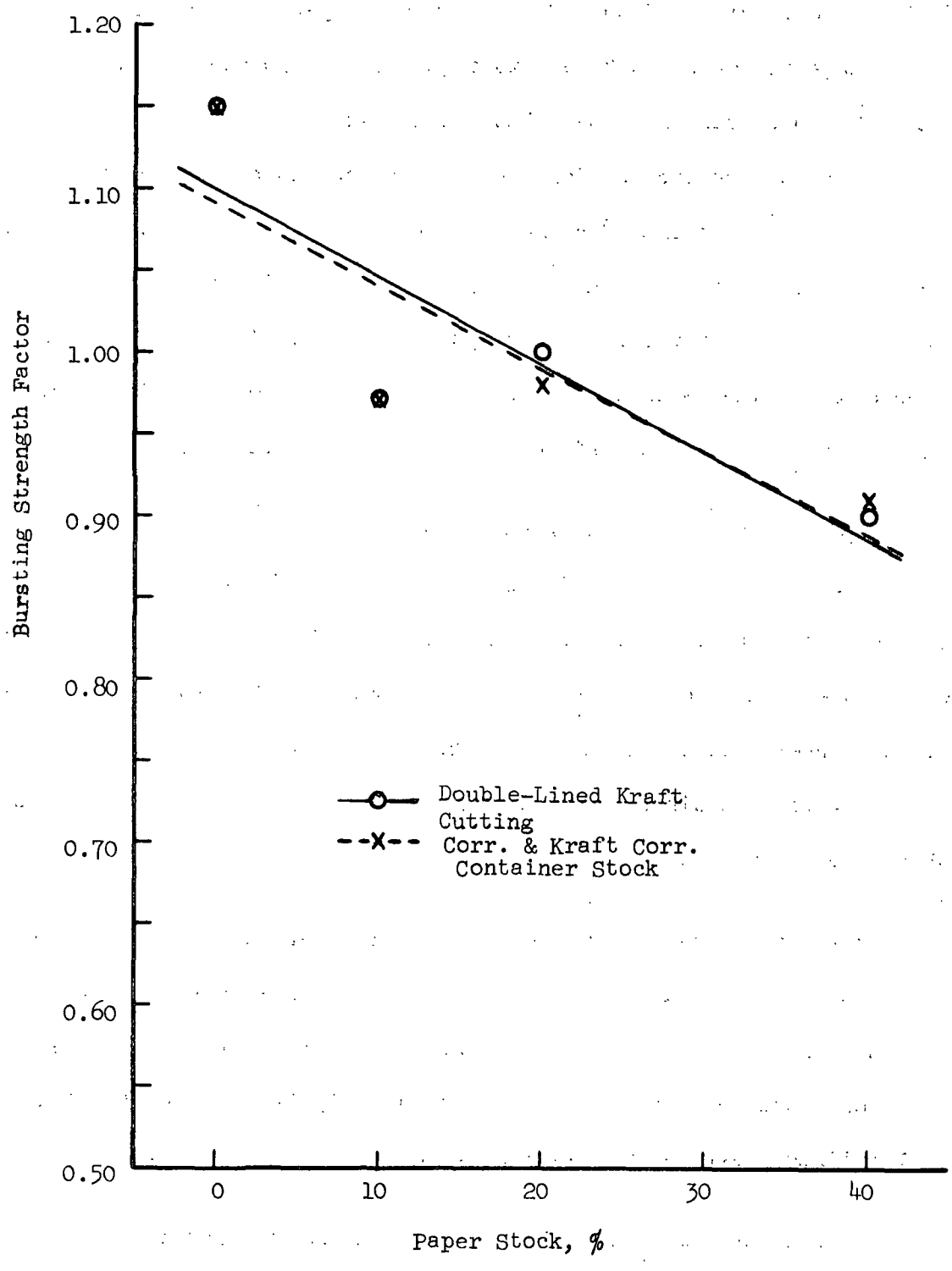

Figure 29. Comparison of Relationship Between Bursting Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 335/205)

double-lined kraft cuttings and corrugated containers — may be seen in Fig. 25-29. Figure 25 gives a comparison of the effect of the two paper stocks on the bursting strength-percentage of paper stock relationship for the 590-585 and 575-ml. furnishes. It may be observed that the relationships were essentially the same, although the correlation coefficient for the furnish containing double-lined kraft cutting was slightly higher than for the furnish with corrugated container stock. The corresponding comparison for the 590/355 furnishes is illustrated in Fig. 26, wherein it may be seen that the relationships are essentially the same; however, again the results obtained with the furnish containing the double-lined kraft cuttings exhibited a considerably higher correlation coefficient.

A comparison of the bursting strength-paper stock relationships obtained for the 585/205 furnishes is illustrated in Fig. 27. Although the relationships are not markedly different, the adverse effect on bursting strength is greater for the furnish containing the corrugated container paper stock. In this case, the correlation coefficient for the results obtained with the furnish containing corrugated container stock was slightly higher than for the furnish using double-lined kraft cuttings.

A comparison of the relationships obtained when varying percentages of the two paper stocks were added to the 355-ml. kraft furnish are shown in Fig. 28 and 29. In both cases, it may be noted that the relationships are essentially the same, although the correlation coefficients were higher for the furnish containing double-lined kraft corrugated cuttings.

In order to show more clearly the effect which the addition of paper stock to a kraft furnish has on bursting strength, the percentage change in bursting strength has been computed using the regression equations tabulated in Table IV. The results are plotted in Fig. 30 and 31.

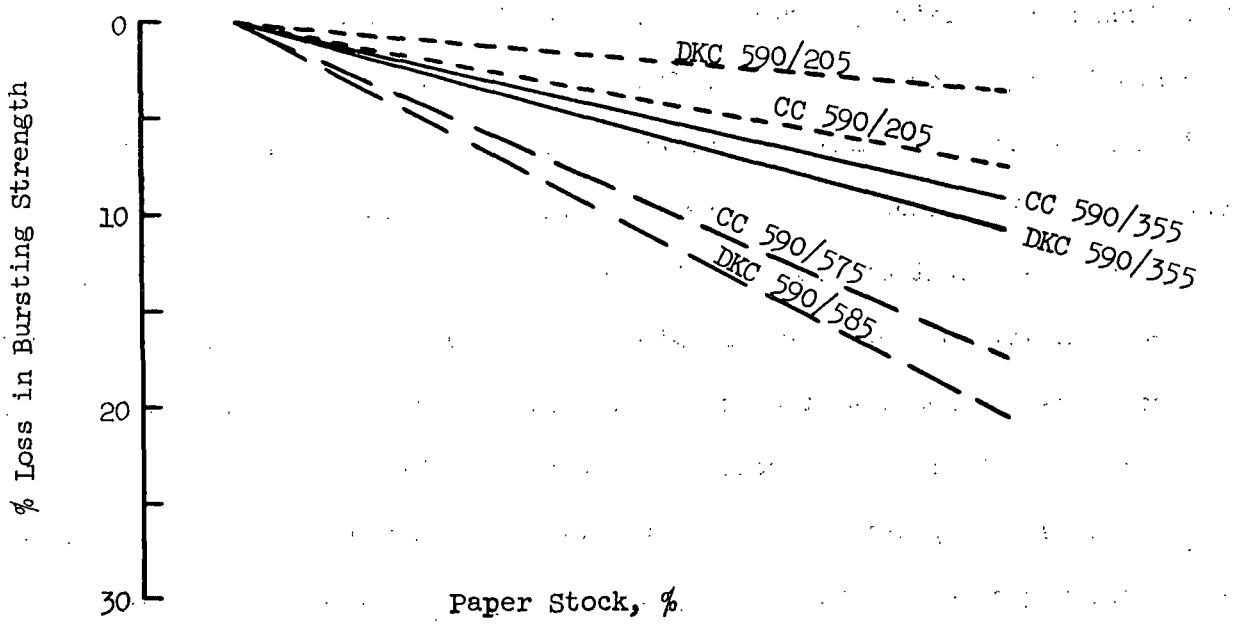

Figure 30. Relationship Between Percentage of Paper Stock and Loss of Bursting Strength

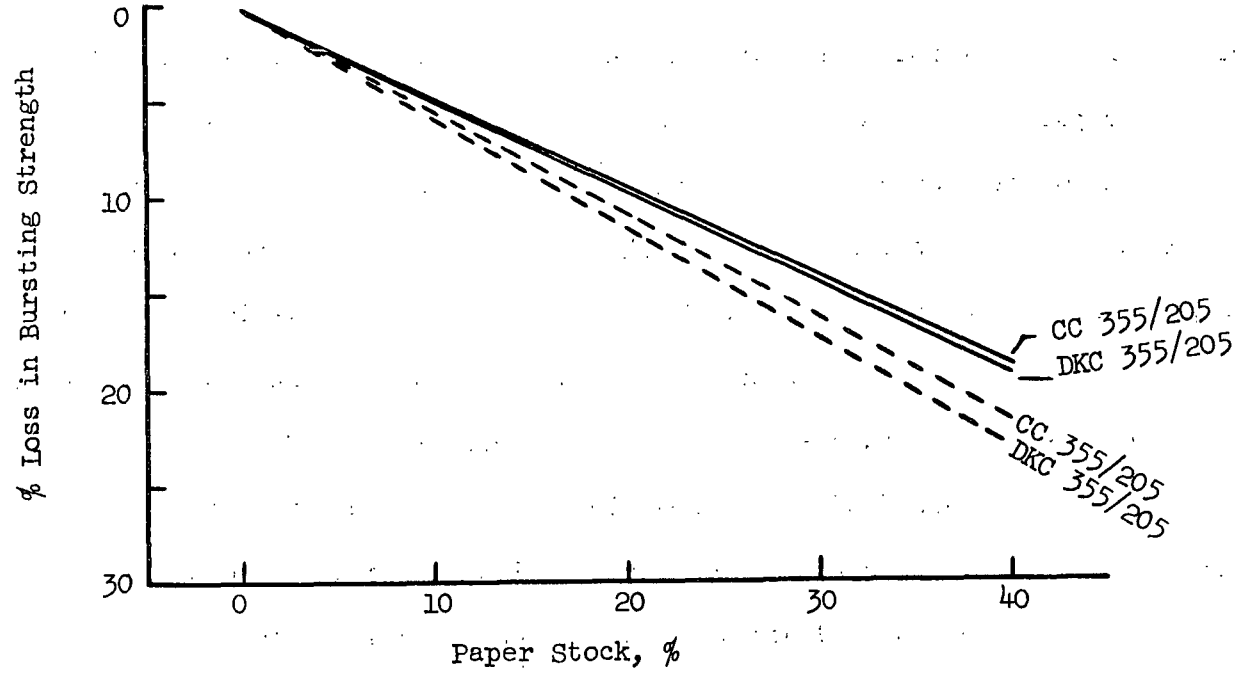

Figure 31. Relationship Between Percentage of Paper Stock and Loss of Bursting Strength

Estimates of the percentage of each paper stock which could be tolerated in the furnish at arbitrary levels of bursting strength loss were determined using the regression equation tabulated in Table IV. The results are plotted in Fig. 30 and 31 adjusted vertically so that each curve passes through the origin. This adjustment probably tends to make the estimates on the conservative side. The estimates of the amount of paper stock the furnish can tolerate before exceeding the selected levels of bursting strength loss are tabulated in Table V. In most cases these results indicate that the double-lined kraft corrugated cuttings are slightly more deleterious to bursting strength than the corrugated container paper stock. This is the opposite of normal practice as the double-lined kraft corrugated cuttings generally contain a higher percentage of kraft fiber and, hence, should develop higher strength.

The regression equations and corresponding correlation coefficients associated with the relationship between tensile strength and the percentage of paper stock in the furnish are given in Table VI and illustrated in Fig. 32-38 for the two paper stocks used in this study. It may be noted in Table VI that some of the correlation coefficients were lower for the tensile relationships than for the bursting strength relationships just discussed. The results plotted in Fig. 32 and 33 for each of the different furnishes at the various freeness levels show the same general trend as was observed with bursting strength except for the results for the furnishes containing double-lined kraft corrugated cuttings at 590/355 and 590/205 freeness levels. In these latter cases the trend is for the tensile strength to increase with increase in the percentage of paper stock; however, it is doubtful if this trend is significant. When the relationships are compared on the basis of the paper stocks used, it may be seen in Fig. 34-38 that except for the cases noted the relationships do not

TABLE V

RELATIONSHIP BETWEEN BURSTING STRENGTH LOSS AND PERCENTAGE OF PAPER STOCK IN THE FURNISH

Bursting Strength Loss, %	Percent Paper Stock in Furnish									
	Kraft Pulp at 590 ml.						Kraft Pulp at 355 ml.			
	DKC[a] at 585 ml.	CC[a] at 575 ml.	DKC[a] at 355 ml.	CC[a] at 355 ml.	DKC[a] at 205 ml.	CC[a] at 205 ml.	DKC[a] at 355 ml.	CC[a] at 355 ml.	DKC[a] at 205 ml.	CC[a] at 205 ml.
2.5	4.5	5.0	9.0	10.5	25.0	12.0	5.0	5.0	5.0	5.0
5.0	9.5	11.0	18.0	21.0	40.0+	25.5	8.5	9.0	10.0	10.0
10.0	19.0	22.5	36.5	40.0+	40.0+	40.0+	17.5	18.5	21.0	21.0
15.0	28.5	33.5	40.0+	--	--	--	26.0	28.0	31.5	32.0
20.0	38.5	40.0+	--	--	--	--	35.0	37.0	40.0+	40.0+

[a]DKC = double-lined kraft corrugated cutting paper stock.
CC = corrugated container paper stock.

TABLE VI

RELATIONSHIP BETWEEN TENSILE STRENGTH AND PERCENTAGE OF PAPER STOCK IN THE FURNISH

Type Furnish	Freeness, ml. Kraft Pulp	Freeness, ml. Paper Stock	Regression Equation[a]	Correlation Coefficient
Kraft pulp-double-lined kraft cutting	590	585	$Y = -0.0016X + 0.497$	-0.835
Kraft pulp-corrugated container stock	590	575	$Y = -0.0012X + 0.484$	-0.865
Kraft pulp-double-lined kraft cutting	590	355	$Y = +0.00019X + 0.496$	+0.620
Kraft pulp-corrugated container stock	590	355	$Y = -0.00045X + 0.497$	-0.471
Kraft pulp-double-lined kraft cutting	590	205	$Y = +0.00029X + 0.497$	+0.494
Kraft pulp-corrugated container stock	590	205	$Y = -0.00036X + 0.494$	-0.705
Kraft pulp-double-lined kraft cutting	355	355	$Y = -0.0013X + 0.565$	-0.930
Kraft pulp-corrugated container stock	355	355	$Y = -0.0017X + 0.560$	-0.902
Kraft pulp-double-lined kraft cutting	355	205	$Y = -0.0017X + 0.579$	-0.983
Kraft pulp-corrugated container stock	355	205	$Y = -0.0013X + 0.568$	-0.939

[a] Y = Tensile factor.
X = Percentage of paper stock.

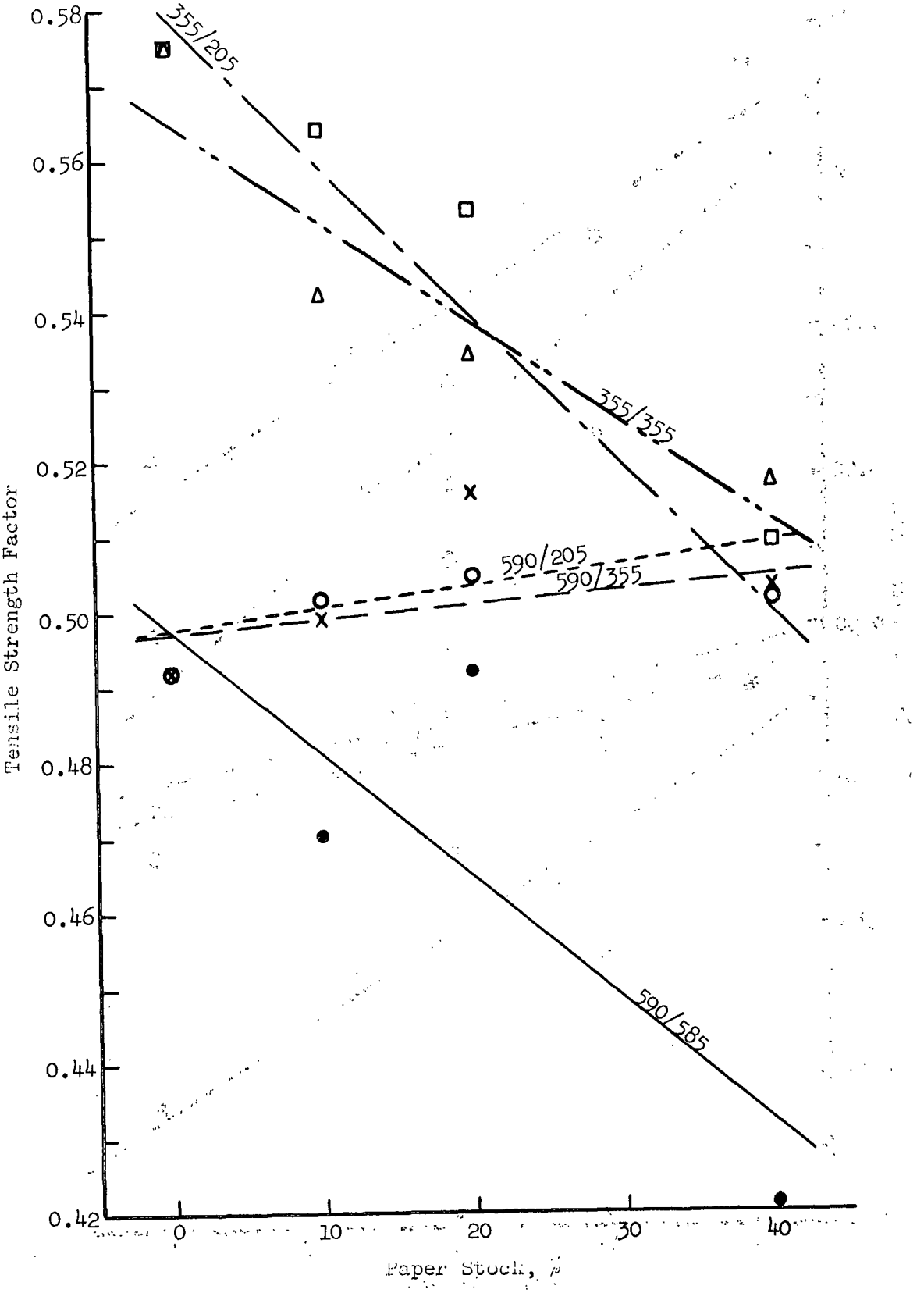

Figure 32. Relationship Between Tensile Strength and Percentage of Double-Lined Kraft Corrugated Cuttings in Furnish

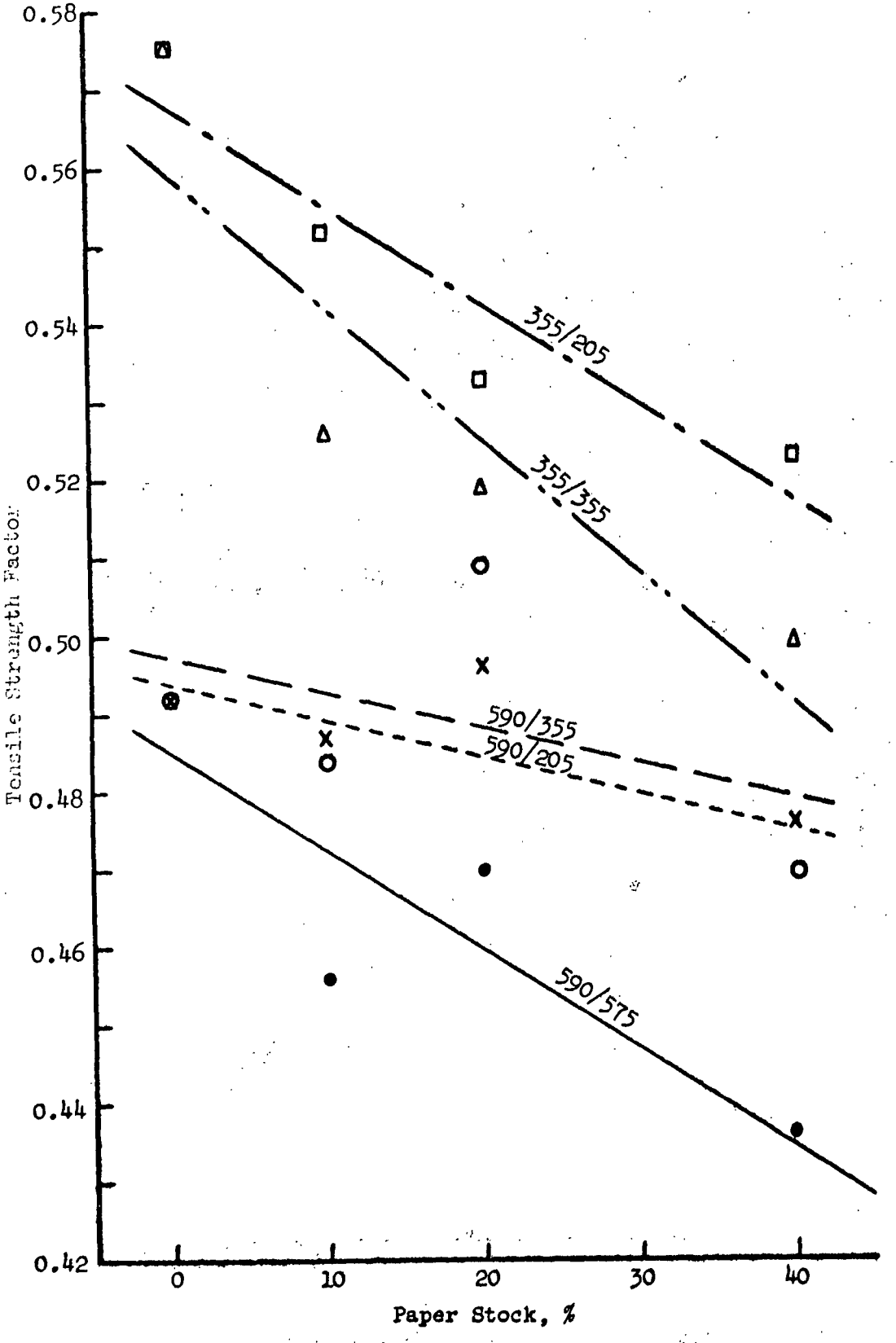

Figure 33. Relationship Between Tensile Strength and Percentage of Corrugated Container Stock in the Furnish

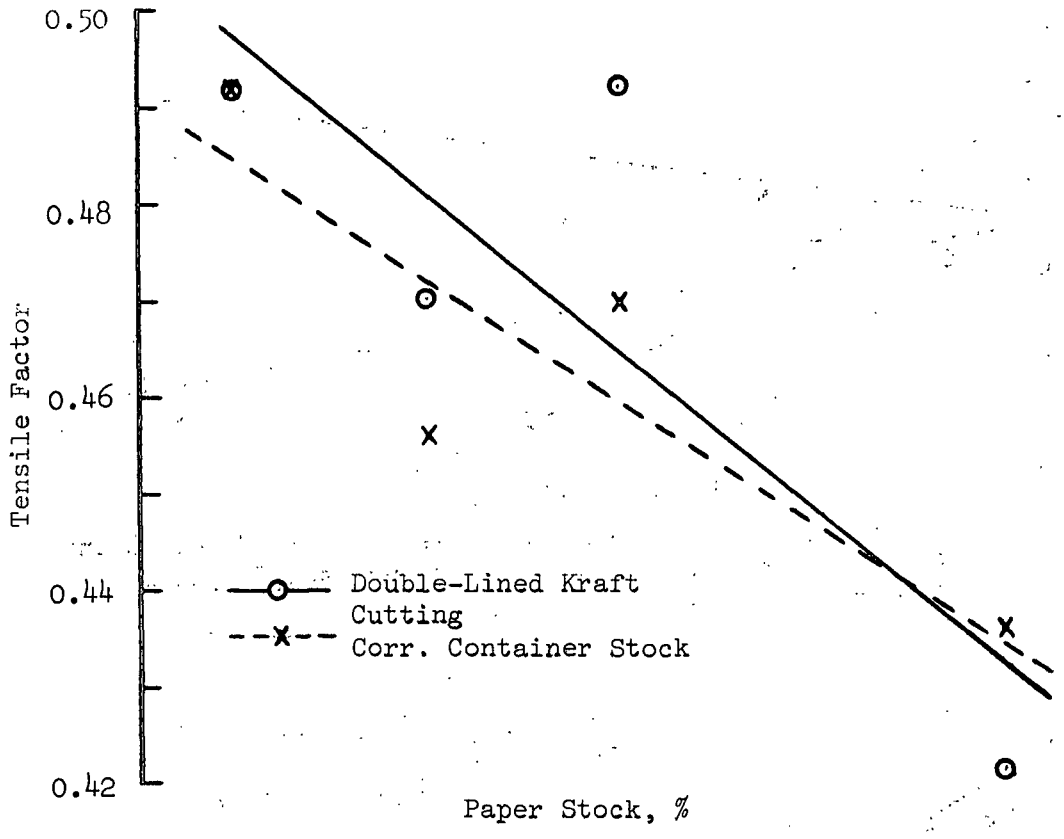

Figure 34. Comparison of Relationship Between Tensile Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/585-575)

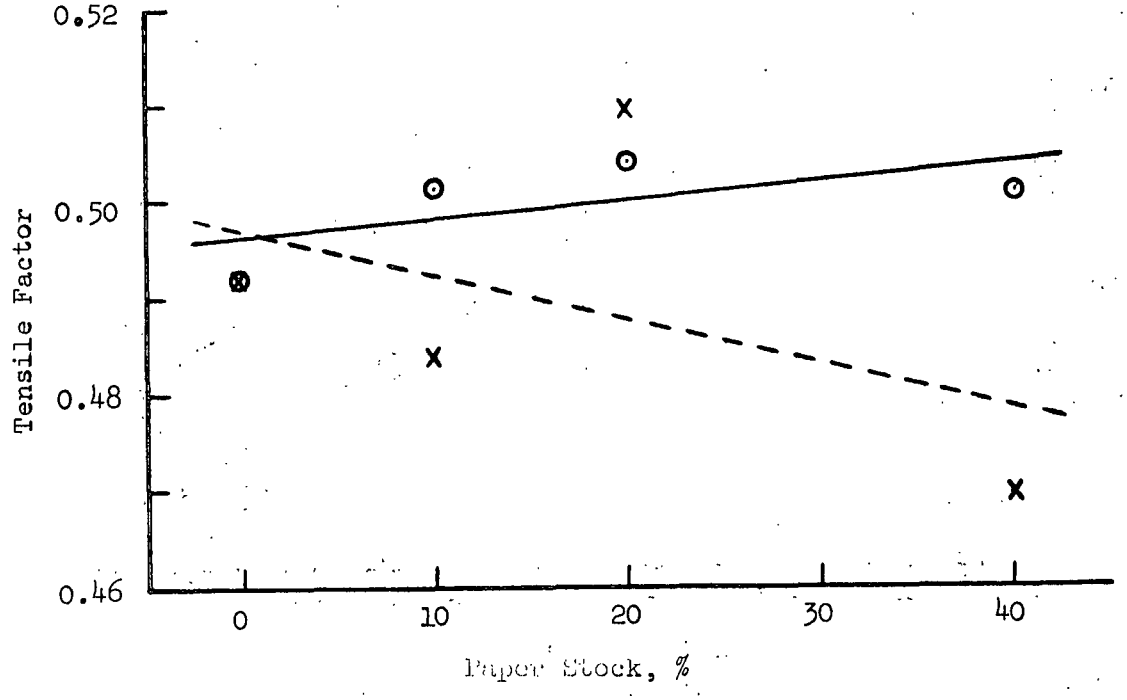

Figure 35. Comparison of Relationship Between Tensile Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/355)

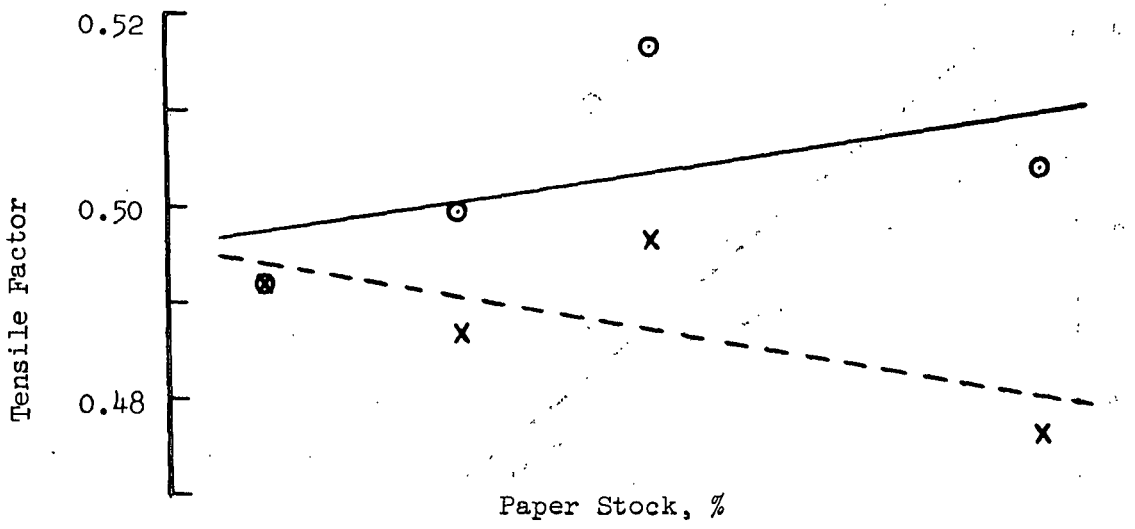

Figure 36. Comparison of Relationship Between Tensile Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/205)

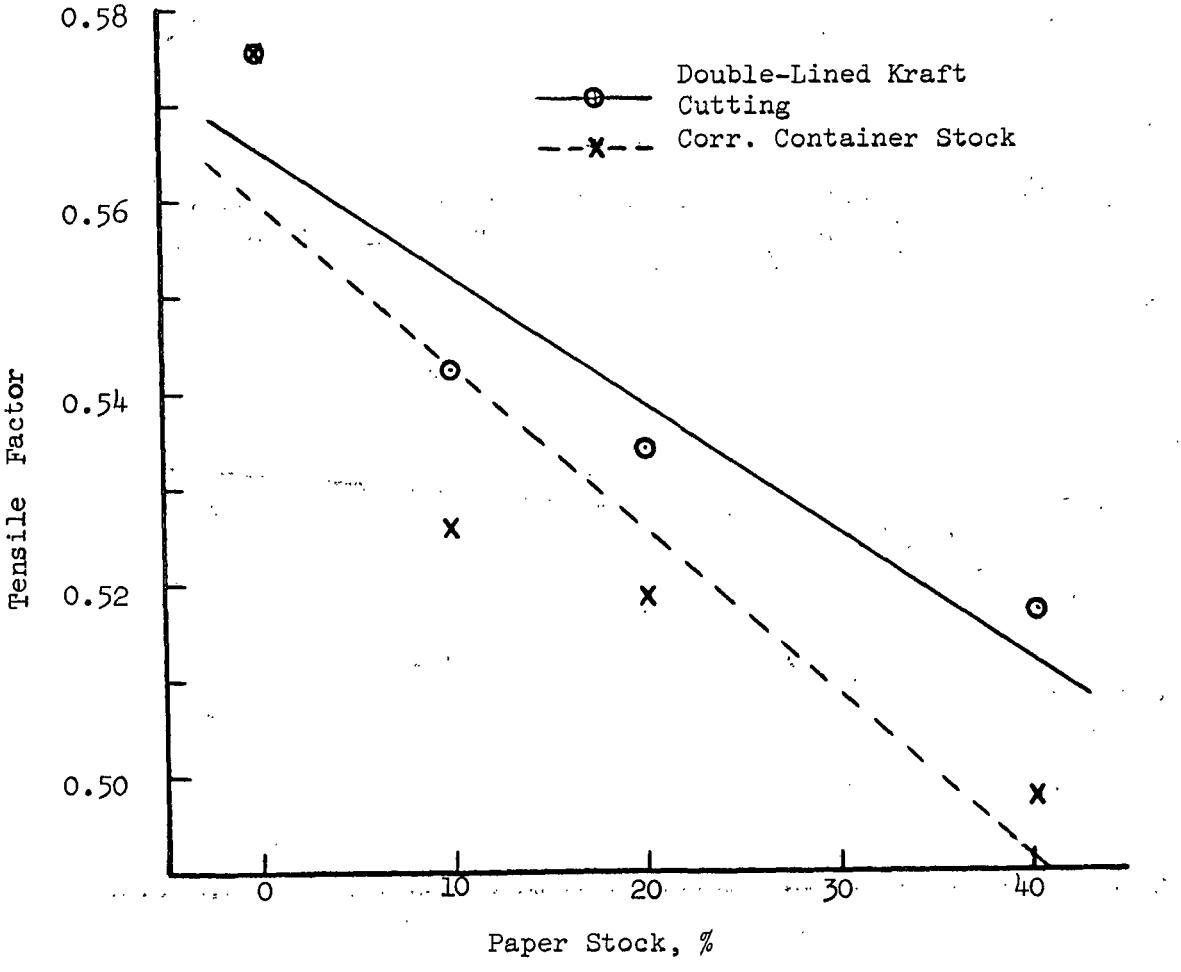

Figure 37. Comparison of Relationship Between Tensile Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 355/355)

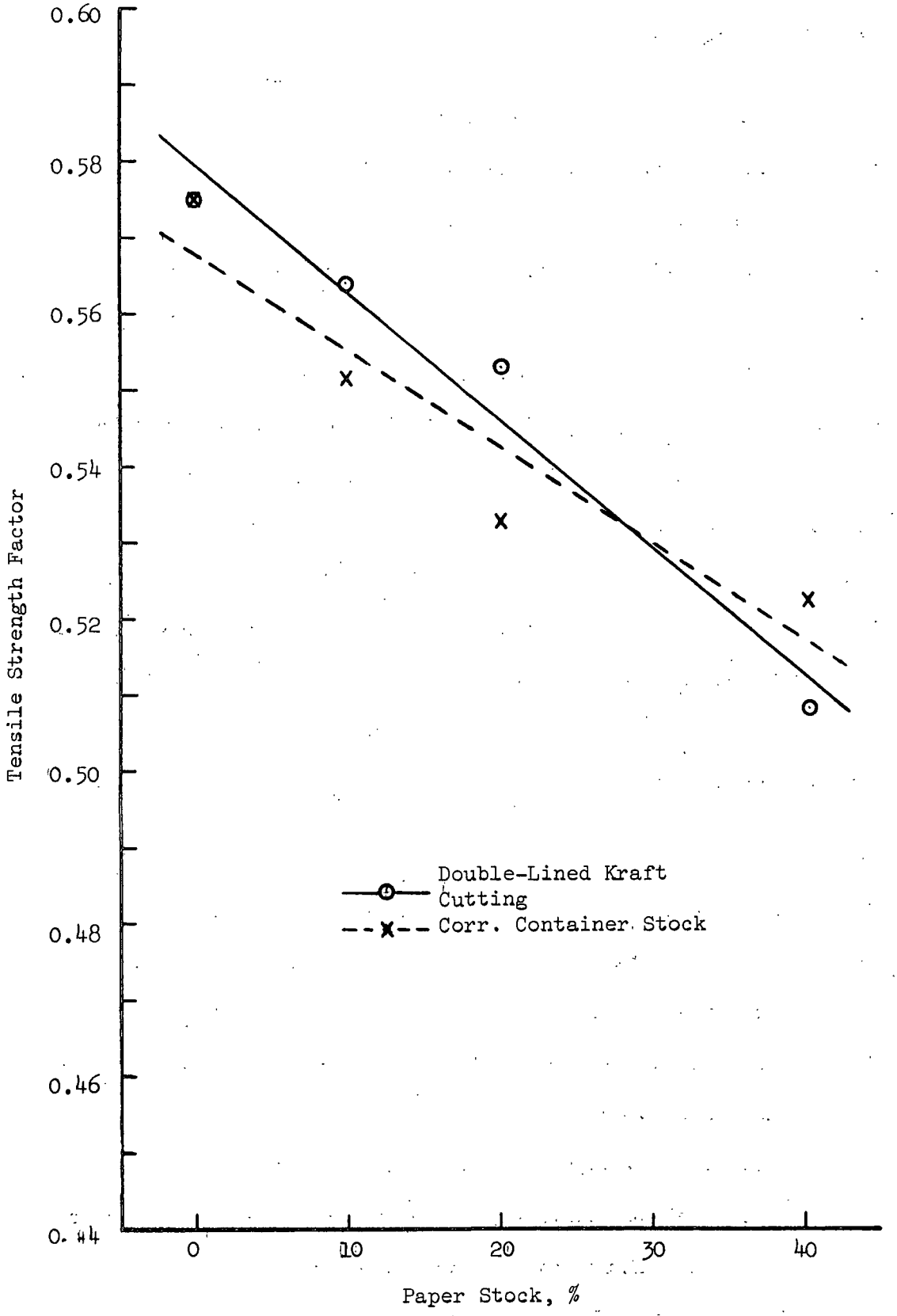

Figure 38. Comparison of Relationship Between Tensile Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 355/205)

appear to have a strong dependency on whether double-lined kraft cuttings or corrugated container stock is used.

The results of the statistical analysis of the effect of the percentage of paper stock in the furnish on edgewise compression are tabulated in Table VII and illustrated in Fig. 39-45. It may be seen in Fig. 39 and 40 that there is a general trend for the edgewise compression resulting from the kraft pulp-paper stock furnishes at freeness levels of 590/585-575, 590/355, and 590/205 ml. to decrease at a slow rate as the percentage of paper stock increases. These relationships are not very strong as shown by the low correlation coefficients in most cases. When the furnishes at 355/355 and 355/205 are considered, there is a slight trend for the edgewise compression to increase with increase in the percentage of the paper stock. This is more evident in the relationship obtained with the 355/205 freeness furnishes; however, these relationships are not very precise as may be noted from the magnitude of the correlation coefficients. Thus, the results indicate that edgewise compression strength is not markedly influenced by the percentage of paper stock used in the range employed in this study.

The empirical relationships and corresponding correlation coefficients associated with the relationship between tearing strength and percentage of paper stock at various freeness levels are tabulated in Table VIII and illustrated in Fig. 46-52. As may be seen in Table VIII, except for one freeness level (590/205), the correlation coefficients range from fairly low to low. One of the reasons for the low degree of correlation may be the use of linear regression. It was pointed out earlier that in may instances tearing strength appeared to increase to a maximum and then decrease with increasing percentage of paper stock in the furnish. Possibly higher correlation coefficients and,

TABLE VII

RELATIONSHIP BETWEEN EDGEWISE COMPRESSION AND PERCENTAGE OF PAPER STOCK IN THE FURNISH

Type Furnish	Freeness, ml. Kraft Pulp	Freeness, ml. Paper Stock	Regression Equation[a]	Correlation Coefficient
Kraft pulp-double-lined kraft cutting	590	585	$Y = -0.00023X + 0.114$	-0.826
Kraft pulp-corrugated container stock	590	575	$Y = -0.000086X + 0.110$	-0.275
Kraft pulp-double-lined kraft cutting	590	355	$Y = -0.000011X + 0.114$	-0.048
Kraft pulp-corrugated container stock	590	355	$Y = -0.000069X + 0.113$	-0.542
Kraft pulp-double-lined kraft cutting	590	205	$Y = -0.00024X + 0.118$	-0.753
Kraft pulp-corrugated container stock	590	205	$Y = -0.000034X + 0.114$	-0.216
Kraft pulp-double-lined kraft cutting	355	355	$Y = -0.00010X + 0.114$	-0.364
Kraft pulp-corrugated container stock	355	355	$Y = +0.000014X + 0.115$	+0.038
Kraft pulp-double-lined kraft cutting	355	205	$Y = +0.00010X + 0.112$	+0.452
Kraft pulp-corrugated container stock	355	205	$Y = +0.00023X + 0.117$	+0.390

[a] Y = Edgewise compression factor.
X = Percentage of paper stock.

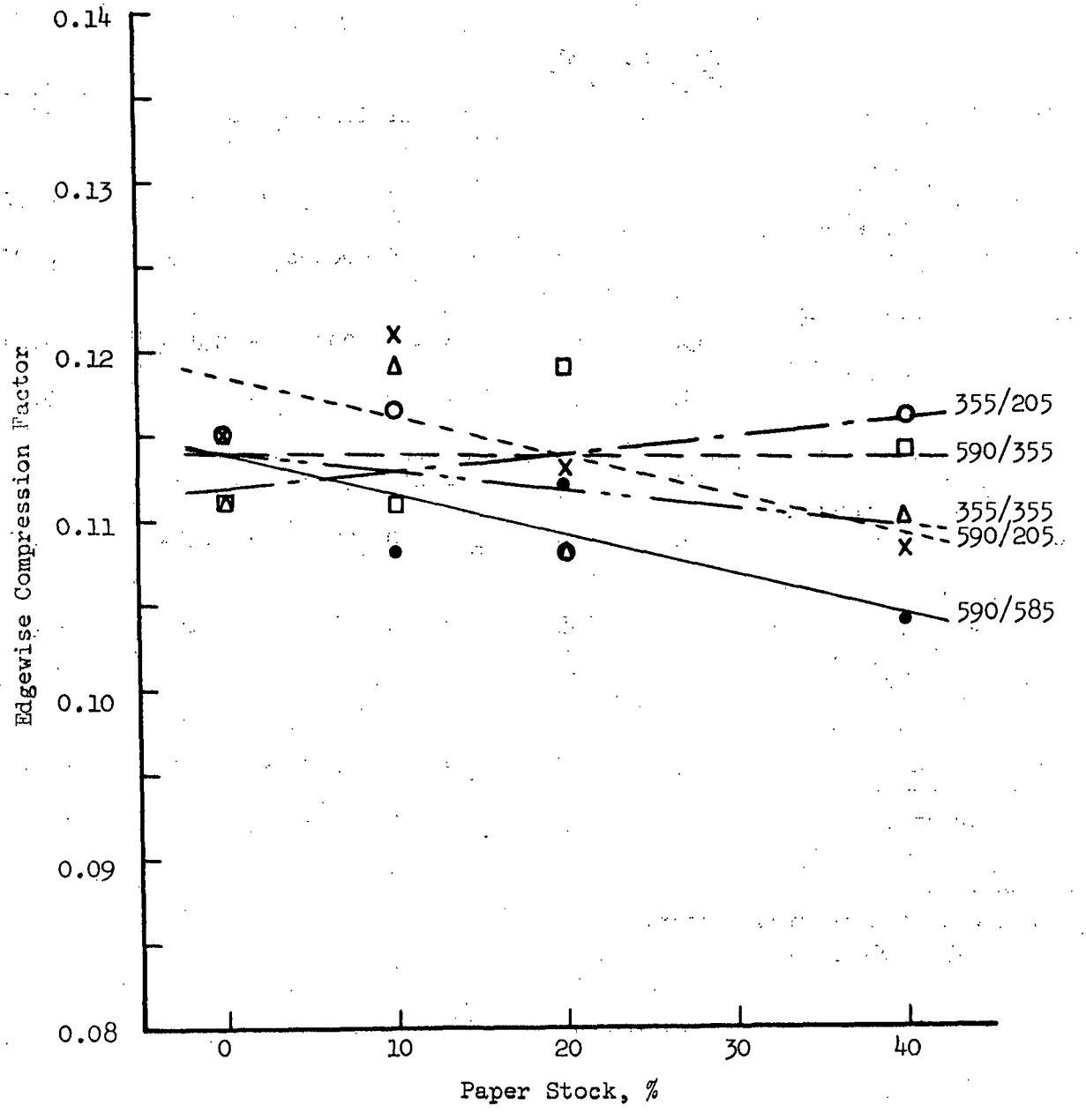

Figure 39. Relationship Between Edgewise Compression Strength and Percentage of Double-Lined Kraft Corrugated Cuttings in the Furnish

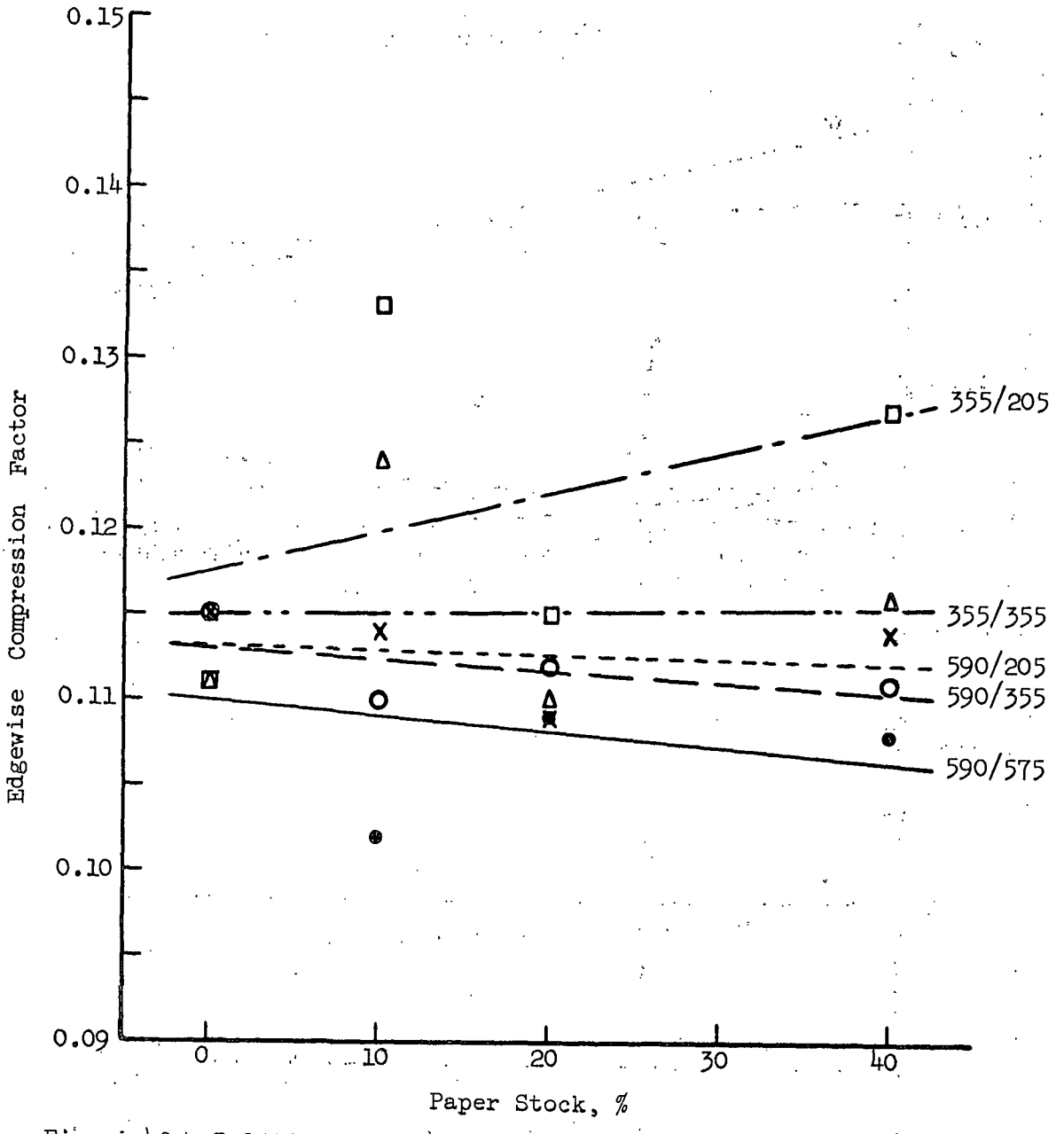

Figure 40. Relationship Between Edgewise Compression Strength and Percentage of Corrugated Container Stock in the Furnish

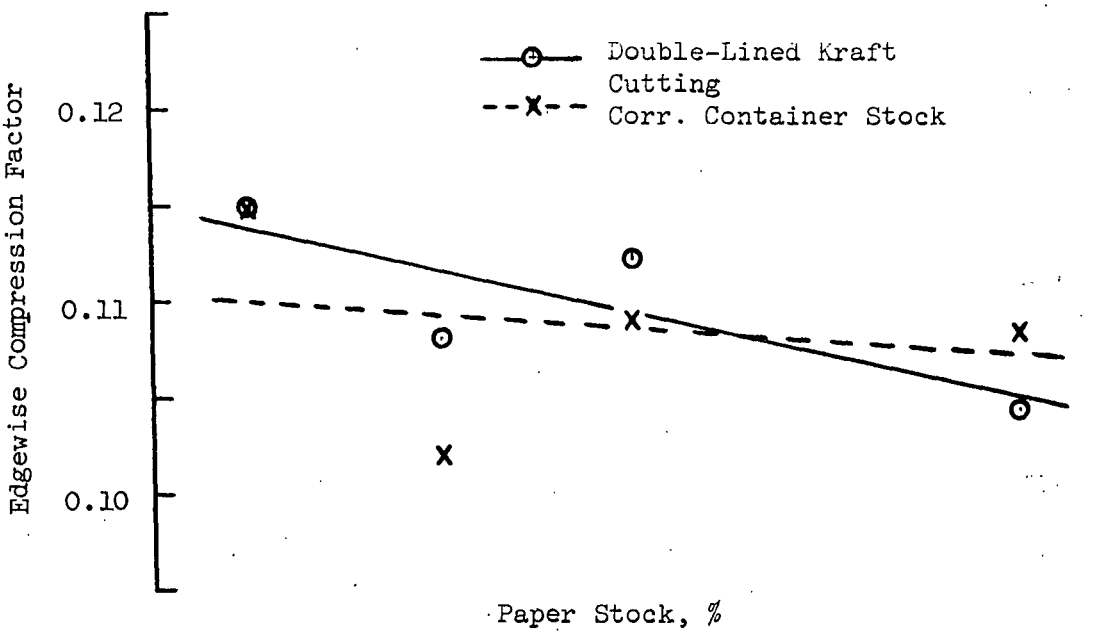

Figure 41. Comparison of Relationship Between Edgewise Compression and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/585-575)

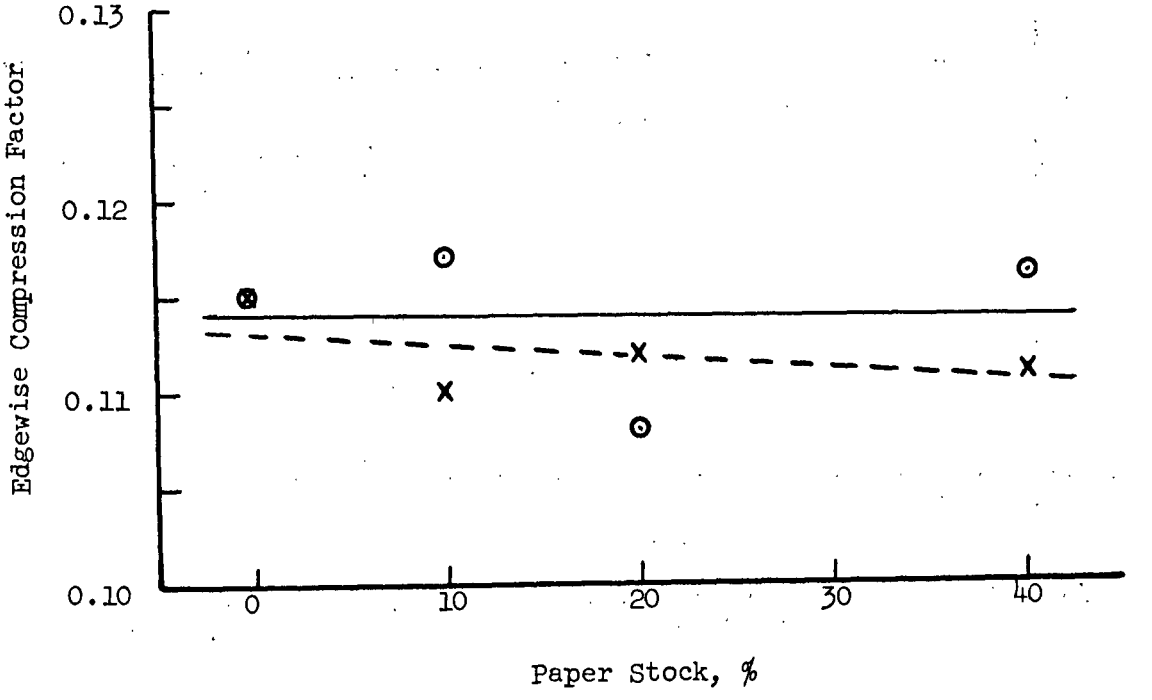

Figure 42. Comparison of Relationship Between Edgewise Compression and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/355)

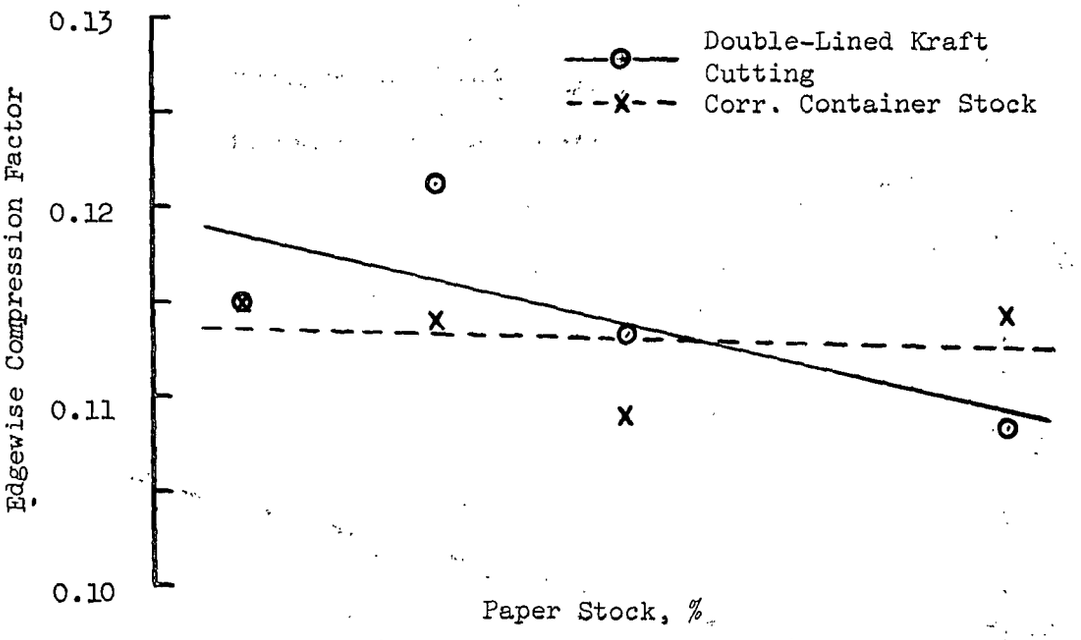

Figure 43. Comparison of Relationship Between Edgewise Compression and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/205).

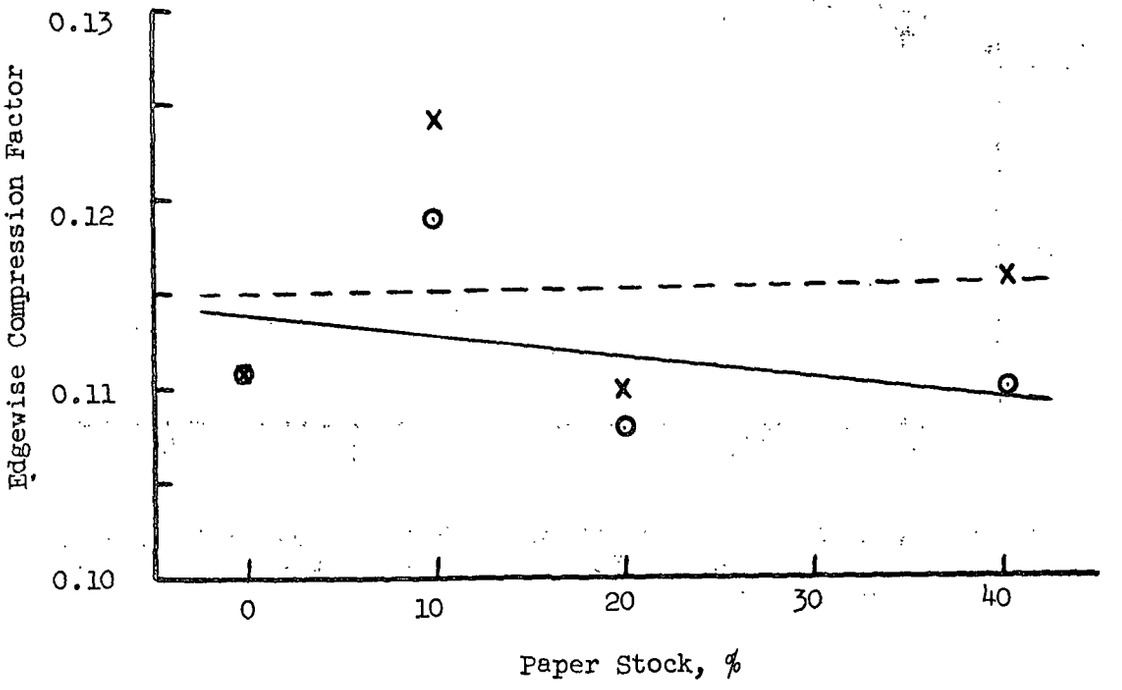

Figure 44. Comparison of Relationship Between Edgewise Compression and Percentage of Paper Stock in the Furnish (Freeness Levels = 355/355)

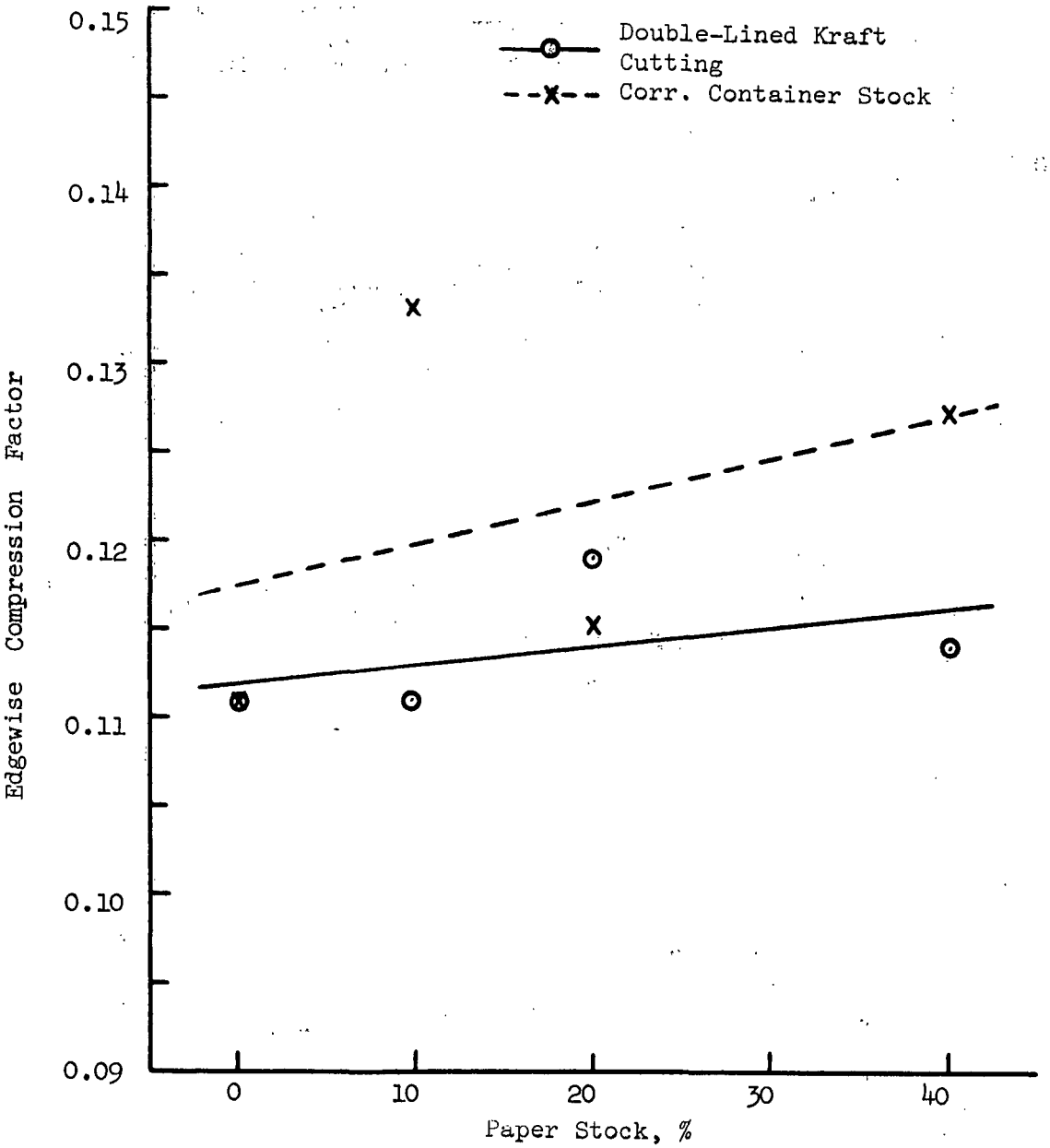

Figure 45. Comparison of Relationship Between Edgewise Compression and Percentage of Paper Stock in the Furnish (Freeness Levels = 355/205)

TABLE VIII

RELATIONSHIP BETWEEN TEARING STRENGTH AND PERCENTAGE OF PAPER STOCK IN THE FURNISH

Type Furnish	Freeness, ml. Kraft Pulp	Freeness, ml. Paper Stock	Regression Equation[a]	Correlation Coefficient
Kraft pulp-double-lined kraft cutting	590	585	$Y = - 0.00097X + 2.182$	-0.165
Kraft pulp-corrugated container stock	590	575	$Y = - 0.00029X + 2.190$	-0.048
Kraft pulp-double-lined kraft cutting	590	355	$Y = - 0.0051X + 2.202$	-0.694
Kraft pulp-corrugated container stock	590	355	$Y = - 0.0022X + 2.134$	-0.794
Kraft pulp-double-lined kraft cutting	590	205	$Y = - 0.0089X + 2.176$	-0.920
Kraft pulp-corrugated container stock	590	205	$Y = - 0.0073X + 2.118$	-0.973
Kraft pulp-double-lined kraft cutting	355	355	$Y = - 0.0071X + 1.950$	-0.696
Kraft pulp-corrugated container stock	355	355	$Y = + 0.0014X + 1.876$	+0.402
Kraft pulp-double-lined kraft cutting	355	205	$Y = + 0.00077X + 1.834$	+0.696
Kraft pulp-corrugated container stock	355	205	$Y = - 0.0021X + 1.882$	-0.410

[a] Y = Tearing strength factor.
X = Percentage of paper stock.

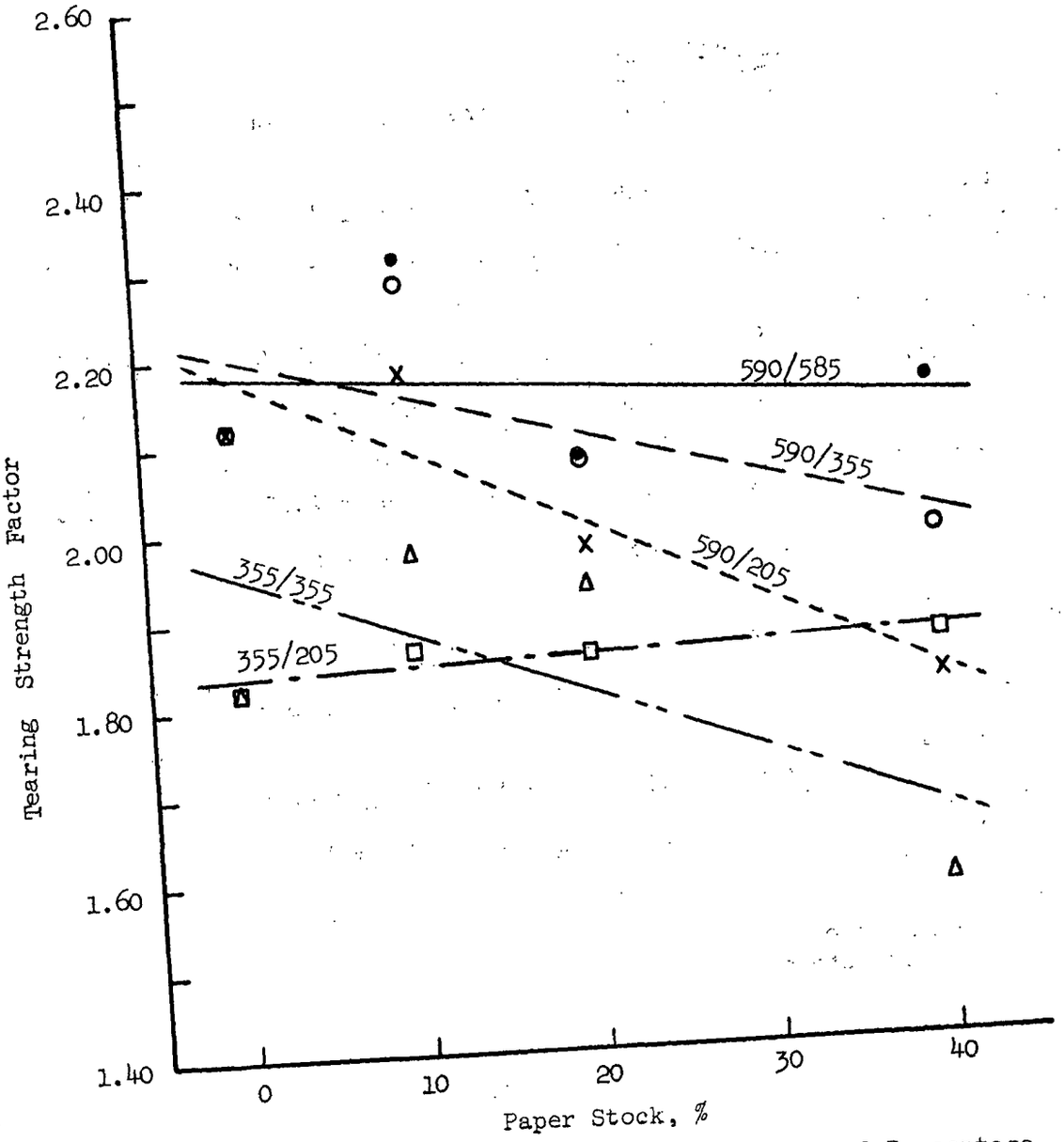

Figure 46. Relationship Between Tearing Strength and Percentage of Double-Lined Kraft Corrugated Cuttings in the Furnish

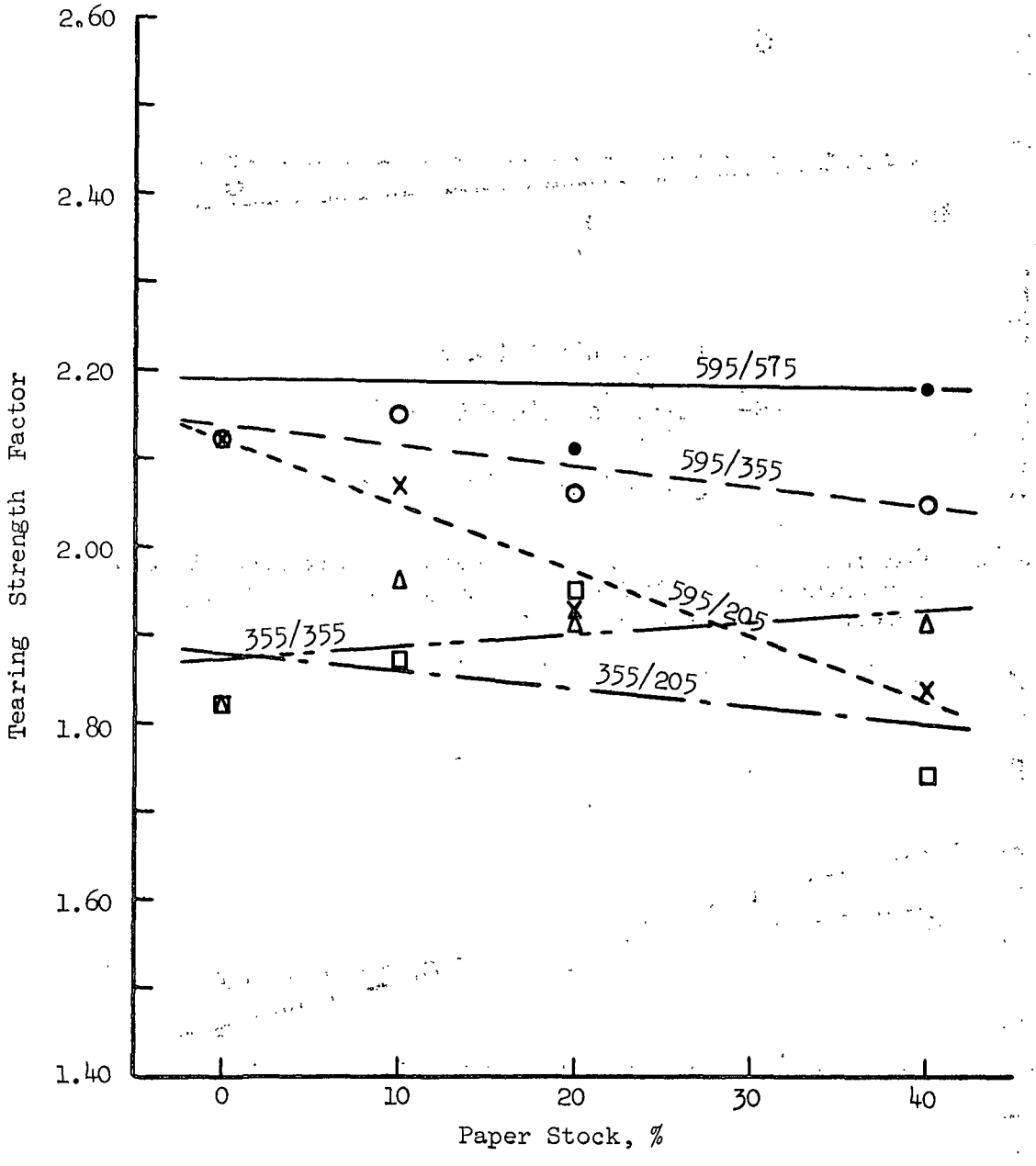

Figure 47. Relationship Between Tearing Strength and Percentage of Corrugated Container Stock in the Furnish

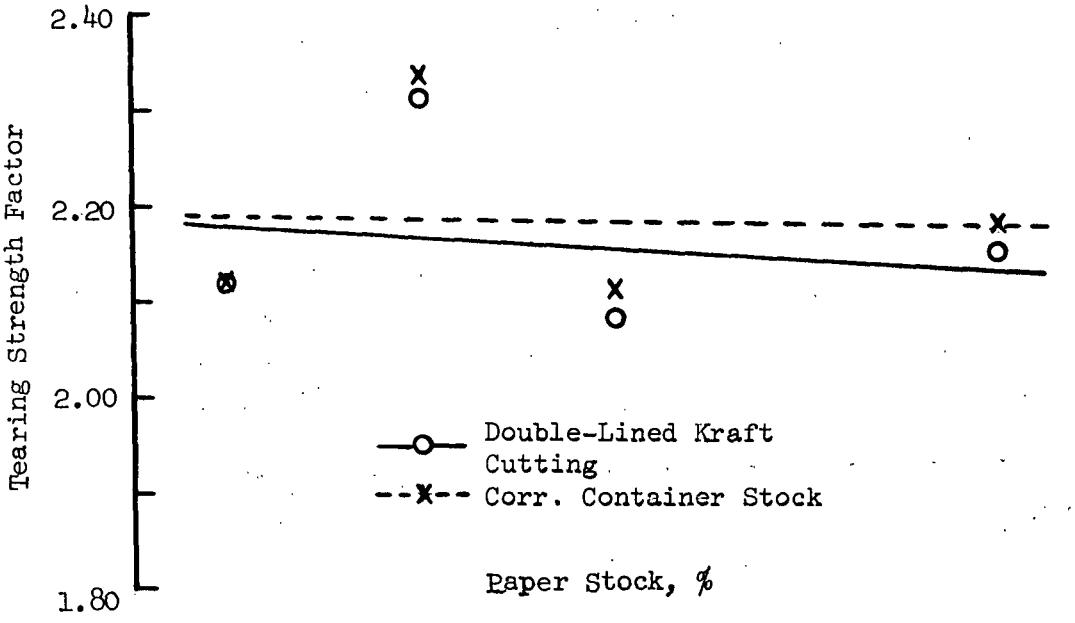

Figure 48. Comparison of Relationship Between Tearing Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/585-575)

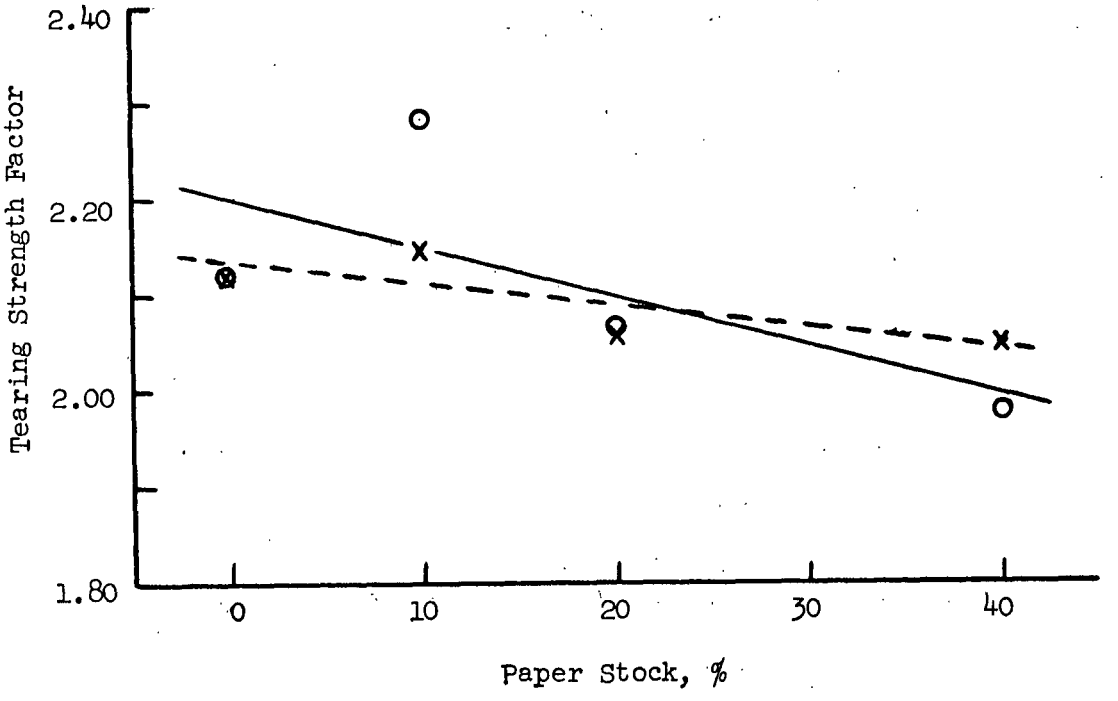

Figure 49. Comparison of Relationship Between Tearing Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/355)

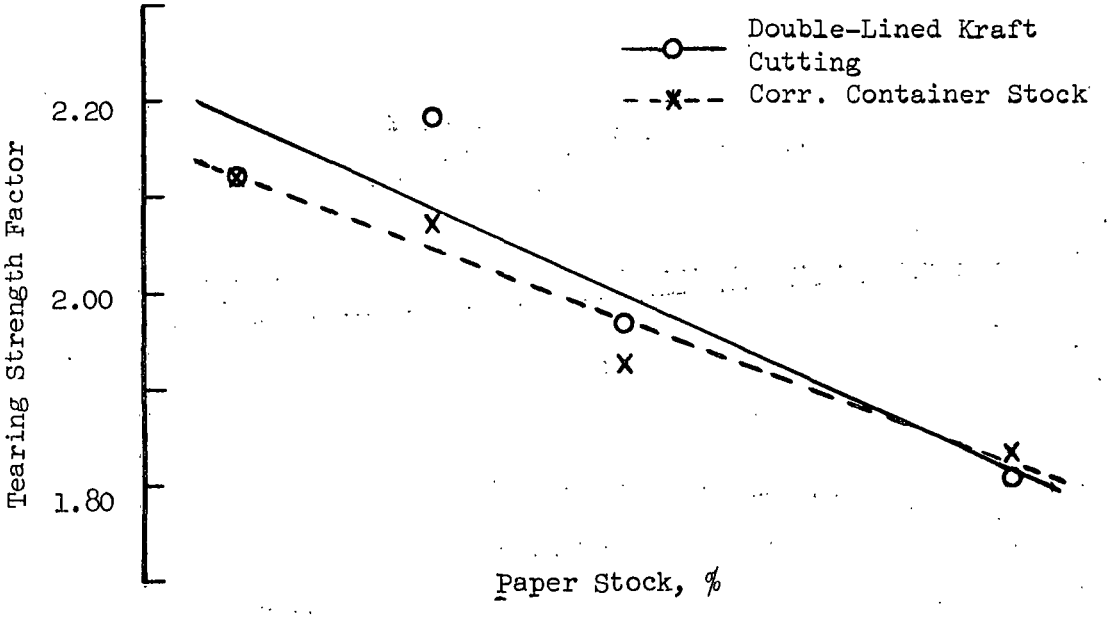

Figure 50. Comparison of Relationship Between Tearing Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 590/205)

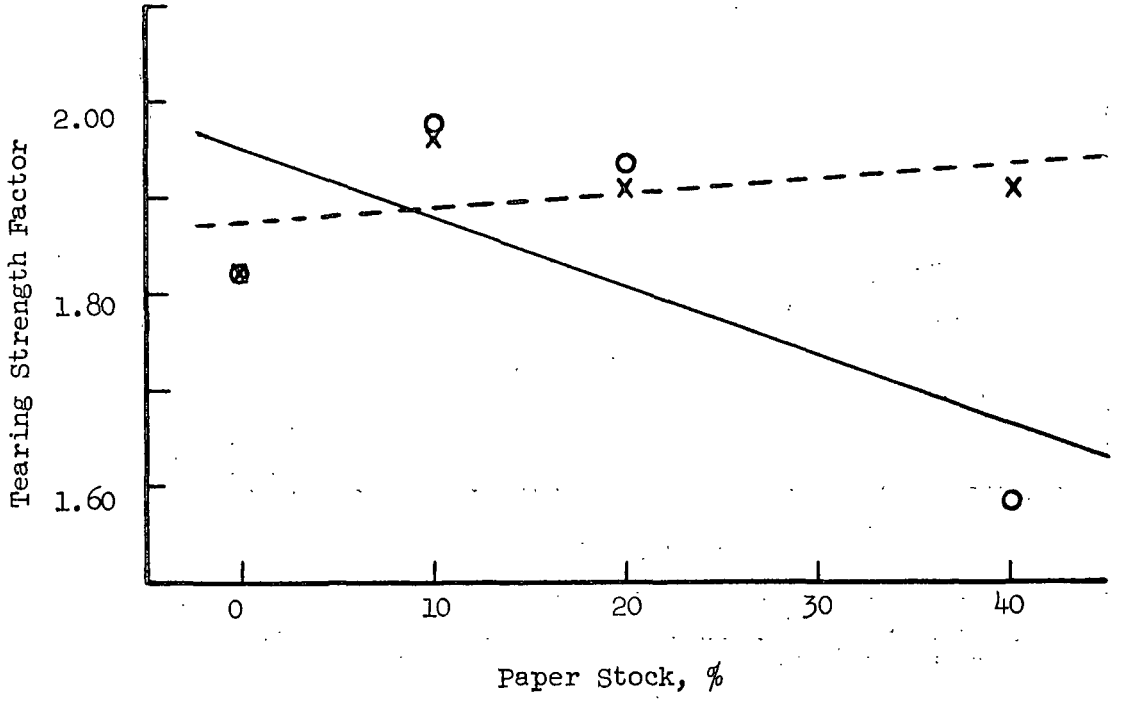

Figure 51. Comparison of Relationship Between Tearing Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 355/355)

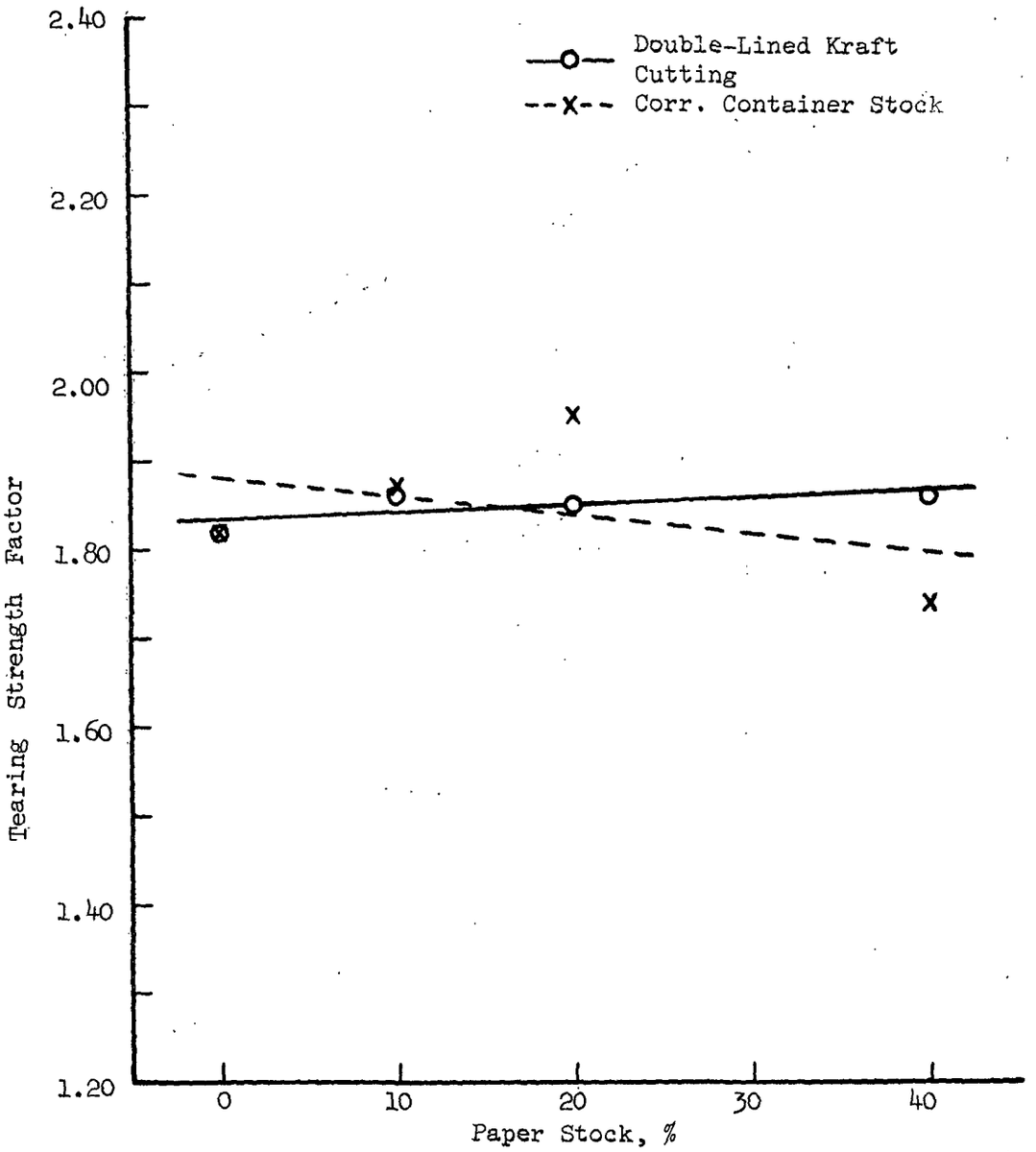

Figure 52. Comparison of Relationship Between Tearing Strength and Percentage of Paper Stock in the Furnish (Freeness Levels = 355/205)

hence, more precise relationships could be developed using nonlinear regression. However, bearing in mind the poor correlation, it may be seen in Fig. 46 and 47 that with the kraft pulp-paper stock furnishes at 590/585-575, 590/355, and 590/205 tearing strength decreased with increase in the percentage of paper stock in the furnish. The lower the freeness of the paper stock the greater the adverse effect on tearing strength. This would be expected based on the mechanics of the tearing strength of paper and board. The results obtained on the kraft pulp-paper stock furnishes at 355/355 and 355/205-ml. freeness levels do not exhibit any clearly definable trend. Also, it may be seen that in most cases (see Fig. 48-52) the type of paper stock has little effect on the relationship between tearing strength and the percentage of paper stock in the furnish.

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